Nano World Journal

https://doi.org/10.17756/nwj.2023-s1-077

Research Article

Open Access

Stochastic Analysis of Elastically Supported FGM Plates Having Varied Plate Thickness Ratio and Aspect Ratio with Elliptical Cutouts in Thermal Environments

Rajesh Kumar*

NIMS University, Jaipur-303121, Rajasthan, INDIA

***Correspondence to:**
Rajesh Kumar
NIMS University, Jaipur, Rajasthan, India.
E-mail: rajeshtripathi63@gmail.com

Received: November 24, 2022
Accepted: April 20, 2023
Published: April 22, 2023

Citation: Kumar R. 2023. Stochastic Analysis of Elastically Supported FGM Plates Having Varied Plate Thickness Ratio and Aspect Ratio with Elliptical Cutouts in Thermal Environments. *NanoWorld J* 9(S1): S397-S402.

Copyright: © 2023 Kumar et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY) (http://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

Abstract

Computational analysis of elastically supported FGM (Functionally Graded Materials) plates in thermal environments is carried out. The basic research is done for plate thickness, varying amplitude ratios, and stiffness support. Outcomes generated by simulation are validated with technique. The applications of such plates are in Aerospace Engineering where weight is of important parameters in consideration with other parameters. Elliptical cutout plates are lighter in weight and maximum stress is developed around cutout to be considered before manufacturing as shown in geometry of plate. Table 1 and Table 2 results are for comparison and validation purposes with published results, Table 3, Table 4, Table 5 and Table 6 results are findings useful for further research reference. Figure 1 shows the geometry of elliptical cutout with dimensions (b,c) for square plate., Figure 2 presents the comparison of SD/ Mean with uncertain parameters studied in this research paper and Figure.3.shows the effects of power index amplitude ratio on mean and coefficient of variations of elliptical cutout plate.

Keywords

Functionally graded materials plates, Uncertain qualities, Elastic supports, Elliptical cutouts

Introduction

FGMs Plates with elliptical, rectangular, and other shapes and sizes have multiple applications in day-to-day life and in modern metallurgy applications. Research is done by Shen [1-3], Huang et al. [4], Yang et al. [5], Wu et al. [6], and Lal et al. [7]. Some other researchers Pandey et al. [8], Shakya et al. [9], and Aydin et al. [10] studied the plate with cutouts. It is evident from the available literatures that no work related to FGM with elliptical cutouts is analysed when plates are resting on elastic foundations having varied plate thickness ratio and aspect ratio and thermal environments is to the best of author's knowledge.

Materials and Methods

Formulations

In the present formulation FGM plates are resting on elastic foundations whose load displacement relation is expresses as

$$P = K_1 w - K_2 \nabla^2 w \quad (1)$$

Strain energy due to elastic foundations, Potential energy is expressed as [14].

$$[K_o]\{q\} = [F_t] \quad K_o = K_b + K_s \quad (2)$$

Higher order shear deformation theory is applied as given in [17].

Comparative study average deforming (Validation of present study)

Table 1 comparison of present Higher Order Shear deformation Theory mean buckling load (Nxb_2/E_2h^3) with semi-analytical buckling load without cutout uniaxial and biaxial. Stacking sequence is varied mentioned below.

Geometry, modeling, and study factors

Results and Discussion

MATLAB [R2010a] coding is done for rectangular holes [10]. A C0 element continuity is expressed in [11]. (Uncertainty at beginning) equal to 0.1 is expressed elaborately in [12, 13]. The assumed basic random input variables (b_i) are sequenced, , where are Young's moduli, Poisson's ratios, coefficient of thermal expansion, Winkler and Pasternak elastic foundations, thermal conductivity of ceramic and metal, respectively and volume fraction index.

$$N^*_{cr} = \frac{N_x b^2}{E_2 h^3}, \quad \lambda_{cr} = \frac{N_{cr} a^2}{\pi^2 D_0}, \quad \text{where } D_0 = \frac{E_c h^3}{12\left(1-v_c^2\right)}$$

Table 2 present Higher Order Shear deformation Theory investigation is carried out for the purpose of validation. The laminates $[0, 90]_2$s is considered. The eight layered thickness are validated with Ghannadpour et al. analytical results [15].

In table 3 it is understood plates supported on elastic foundations deform at higher thermal load compared to without support.

Post buckling load increases on increasing amplitude ratios for plate supports. However, these values further decrease on increase of volume fraction index. It means on increase of power index the buckling tendency increases for given temperature in present study.

In table 4 it is seen that for given volume fraction index the expected mean and Coefficient of Variations of thermal Investigation of plates of Temperature Independent Material Properties, plate thickness ratio (a/h = 30), a = 50, and b = 50. The Elliptical Cutout Major Axis (2d/a) = 20, Minor Axis (2e/a) = 10 is shown in table 5. It is seen that for same aspect ratio on increasing volume fraction index the mean and Coefficient of Variations of thermal post buckling load decreases, however on increasing amplitude ratio for plate without and with Winkler and Pasternak elastic foundations thermal post buckling load increases. Coefficient of Variations for volume fraction index (0.5) is much higher than other so this must be avoided for design purpose.

In table 6 it is seen that for SSSS support and Al/ZrO_2 plate material, on increasing minor axis values the Mean and Coefficient of Variations of thermal post buckling load increases, however on increasing amplitude ratio increase for plate supports and on change to Al/Al_2O_3 plate material.

Post buckling response outputs

Figure 2 comparative graph for SD/Mean with uncertainty in material qualities of present is compared with those published [5, 14]. Figure 3 shows the effects of power index amplitude ratio on elliptical hole plate.

Conclusion

Computational analysis of elastically supported plates in thermal environments is investigated. The average thermal post buckling load of FGM plate subjected to uniaxial compression varies as per shape change. The dimensionless average and coefficient of variations is different for different support. It concludes that when plates with Elliptical cutouts are on support1 and support 2. Post deforming is at higher temperature for same properties compared to without foundations.

Table 1: Present results are validated with Ghandapour et al. [15] and Sneha and Kadam [16].

	Without cutout Uniaxial			Without cutout Biaxial	
Stacking Sequence	Ghandapour et al. [15]	Sneha et al. [16]	Present Higher Order Shear deformation Theory	Sneha et al. [16]	Present Higher Order Shear deformation Theory
(0/90)2s	16.55	16.54	16.8619	8.27	8.3550
[30/-30]2s	23.16	23.37	23.8519	11.684	11.8503
(45/-45)2s	25.92	25.65	25.7946	12.826	12.5792

Table 2: Comparison of present Higher Order Shear deformation Theory mean buckling load (Nxb_2/E_2h^3) with semi-analytical buckling load of elliptical hole with for varying (d/b), (e/b).

(d/b)	(e/b)	Buckling load (Nxb_2/E_2h^3)	
		Ghannadpour et al. [15]	Investigated Results
0.0	0.0	13.79	13.88
0.5	0.05	13.11	13.40
0.5	0.10	12.19	12.37
0.5	0.15	11.32	11.43
0.5	0.20	10.49	10.53
0.5	0.25	9.70	9.66

Table 3: Plate studied for mean thermal post buckling load with elliptical hole, Temperature Independent Material Properties material properties, (a/h) = 20, (a/b = 1), (a = 50), (Width b = 50), for varying power Index(n), amplitude ratios (W_{max}/h = 0.0 - 1.0).

a/h	n	W_{max}/h	Hole shape					
			($k_1 = 0, k_2 = 0$)		Support1		Support2	
			Average	*SD/Average*	Average	*SD/Average*	Average	*SD/Average*
20	0.0	0.0	0.4802	0.1013	0.5263	0.1014	0.6435	0.1009
		0.5	0.5203	0.1075	0.5664	0.1079	0.6853	0.1071
		1.0	0.6391	0.1252	0.6879	0.1256	0.8118	0.1243
	0.5	0.0	0.3164	0.0876	0.3615	0.0896	0.4739	0.0912
		0.5	0.3457	0.0933	0.3912	0.0954	0.5078	0.0965
		1.0	0.4320	0.1095	0.4762	0.1121	0.6010	0.1035
	1.0	0.0	0.2449	0.0865	0.2892	0.0875	0.3971	0.0876
		0.5	0.2688	0.0965	0.3140	0.0972	0.4279	0.0953
		1.0	0.3379	0.1103	0.3869	0.1105	0.4983	0.1031
	2.0	0.0	0.1903	0.1032	0.2332	0.0971	0.3356	0.0901
		0.5	0.2087	0.1180	0.2531	0.1125	0.3628	0.1015
		1.0	0.2619	0.1276	0.3111	0.1218	0.4272	0.0904
	5.0	0.0	0.1559	0.0980	0.1972	0.0904	0.2947	0.0828
		0.5	0.1687	0.1134	0.2117	0.1058	0.3154	0.0921
		1.0	0.2061	0.1251	0.2535	0.1183	0.3731	0.0977
	10.0	0.0	0.1396	0.0820	0.1799	0.0783	0.2751	0.0749
		0.5	0.1499	0.0945	0.1919	0.0897	0.2925	0.0801
		1.0	0.1801	0.1098	1.3519	0.4000	0.3412	0.0879

Table 4: Late studied for mean thermal post buckling load with elliptical hole, Temperature Independent Material Properties material properties, Plate thickness ratio (a/h) = 10, (a/b = 1), (a = 50), (Width b =50). for varying power Index(n), amplitude ratios (W_{max}/h = 0.0 - 1.0).

n	W_{max}/h	Hole shape					
		($k_1 = 0, k_2 = 0$)		Support1		Support2	
		Average	*SD/Average*	Average	*SD/Average*	Average	*SD/Average*
0.0	0.0	3.1413	0.1013	3.4849	0.1014	4.3616	0.1008
	0.5	3.4504	0.1086	3.6409	0.1088	4.6914	0.1081
	1.0	4.3536	0.1277	4.5830	0.1217	5.4103	0.1274
0.5	0.0	2.0789	0.0877	2.4148	0.0900	3.2523	0.0916
	0.5	2.3044	0.0943	2.6460	0.0967	3.5022	0.0969
	1.0	2.8771	0.1076	3.1012	0.1152	4.0885	0.0991
1.0	0.0	1.6105	0.0858	1.9376	0.0870	2.7409	0.0874
	0.5	1.7940	0.0954	2.1303	0.0963	4.1123	0.1902
	1.0	2.3160	0.1140	2.7170	0.1343	3.1111	0.0985
2.0	0.0	1.2465	0.1001	1.5583	0.0937	2.3203	0.0872
	0.5	1.3879	0.1132	1.7121	0.1068	2.4942	0.0944
	1.0	1.7970	0.1245	2.0649	0.1189	2.8901	0.1106
5.0	0.0	1.0047	0.0941	1.2906	0.0859	2.0105	0.0790
	0.5	1.1034	0.1081	1.2945	0.0866	2.1712	0.0851
	1.0	1.3705	0.1073	1.6724	0.1085	2.2428	0.0872
10.0	0.0	0.8951	0.0812	1.1670	0.0769	1.8699	0.0737
	0.5	0.9745	0.0935	1.2657	0.0876	2.0062	0.0774
	1.0	1.1963	0.1023	1.4958	0.1023	2.3681	0.1412

Table 5: Plate studied for mean thermal post buckling load with elliptical hole, Temperature Independent Material Properties material properties. (a/h = 30). Plate dimensions Length and Width for varying plate (a/b), power index(n), W_{max}/h = 0.0 - 1.0.

a/b	n	W_{max}/h	Hole shape					
			($k_1 = 0, k_2 = 0$)		Support1		Support2	
			Average	*SD/Average*	Average	*SD/Average*	Average	*SD/Average*
1	0.0	0.0	0.1584	0.1013	0.1722	0.1014	0.2079	0.1009
		0.5	0.1707	0.1075	0.1847	0.1078	0.2209	0.1071
		1.0	0.2069	0.1231	0.2212	0.1235	0.2591	0.1221
	0.5	0.0	0.1043	0.0876	0.1178	0.0894	0.1519	0.0909
		0.5	0.1133	0.0934	0.1271	0.0952	0.1627	0.0962
		1.0	0.1397	0.1083	0.1543	0.1098	0.1925	0.0970
	1.0	0.0	0.0807	0.0867	0.0940	0.0875	0.1266	0.0875
		0.5	0.0881	0.0971	0.1018	0.0978	0.1368	0.0958
		1.0	0.1096	0.1104	0.1245	0.1106	0.1589	0.0903
	2.0	0.0	0.0628	0.1040	0.0757	0.0982	0.1065	0.0914
		0.5	0.0685	0.1197	0.0819	0.1147	0.1160	0.1041
		1.0	0.0850	0.1288	0.1001	0.1212	0.1346	0.0917
	5.0	0.0	0.0516	0.0987	0.0641	0.0917	0.0936	0.0842
		0.5	0.0556	0.1150	0.0687	0.1083	0.1393	0.1007
		1.0	0.0671	0.1266	0.0818	0.1197	0.1896	0.1461
	10.0	0.0	0.0463	0.0822	0.0585	0.0787	0.0873	0.0752
		0.5	0.0494	0.0950	0.0623	0.0907	0.1241	0.0904
		1.0	0.0587	0.1101	0.0737	0.1028	0.1588	0.1274
2	0.0	0.0	0.3309	0.1046	0.3343	0.1053	0.3771	0.1140
		0.5	0.3944	0.1595	0.5395	0.4392	0.4114	0.2863
		1.0	0.4980	0.1795	0.5632	0.8283	1.1249	0.0863
	0.5	0.0	0.2435	0.0920	0.2475	0.0923	0.2976	0.0948
		0.5	0.1919	0.4952	0.2001	0.4610	0.5681	0.0983
		1.0	0.4696	0.0837	0.3492	0.2912	0.4889	0.0828
	1.0	0.0	0.1927	0.0842	0.1969	0.0848	0.2488	0.0911
		0.5	0.1423	0.4160	0.1485	0.3718	0.2119	0.2658
		1.0	0.1375	0.5562	0.3354	0.0927	0.4086	0.0780
	2.0	0.0	0.1381	0.0751	0.1419	0.0759	0.1885	0.0859
		0.5	0.2826	0.0765	0.1752	0.0944	0.2108	0.1464
		1.0	0.2226	0.1687	0.2757	0.1121	0.1446	0.8128
	5.0	0.0	0.0663	0.2829	0.0705	0.2694	0.1212	0.1857
		0.5	0.0249	1.7197	0.0298	0.4243	0.1140	0.2703
		1.0	0.0633	0.4730	0.1747	0.0773	0.1054	0.6365
	10.0	0.0	0.0328	0.6775	0.0373	0.5833	0.0870	0.2298
		0.5	0.1089	0.1407	0.1118	0.1372	0.0719	0.5739
		1.0	0.1983	0.0757	0.1235	0.1989	0.1052	0.5015

Table 6: Plate studied for mean thermal post buckling load with elliptical cutouts, Temperature Independent Material Properties material properties, a/h = 20, n = 5.0, Elliptical Cutout Major Axis (2d/a) = 25 for different type of materials (Al/ZrO_2), (Al/Al_2O_3), variations in Minor Axis, Amplitude ratios (W_{max}/h = 0.0 - 1.0).

Type of material	Minor Axis (2e/a)	W_{max}/h	Hole shape					
			($k_1 = 0, k_2 = 0$)		Support1		Support2	
			Average	*SD/Average*	Average	*SD/Average*	Average	*SD/Average*
Al/ZrO_2	0.0	0.0	0.2178	0.0754	0.2604	0.0737	0.3597	0.0727
		0.5	0.2347	0.0890	0.2779	0.0849	0.3792	0.0789
		1.0	0.2839	0.1107	0.3289	0.1058	0.4358	0.0956
	0.1	0.0	0.2226	0.0754	0.2664	0.0737	0.3691	0.0727
		0.5	0.2405	0.0885	0.2848	0.0843	0.3897	0.0786
		1.0	0.2926	0.1093	0.3386	0.1044	0.4495	0.0945
	0.2	0.0	0.2349	0.0753	0.2793	0.0736	0.3851	0.0725
		0.5	0.2540	0.0878	0.2989	0.0838	0.4075	0.0783
		1.0	0.3097	0.1076	0.3565	0.1029	0.4727	0.0934
	0.3	0.0	0.2538	0.0753	0.2981	0.0735	0.4065	0.0722
		0.5	0.2743	0.0871	0.3196	0.0835	0.4318	0.0780
		1.0	0.3342	0.1059	0.3826	0.1016	0.5055	0.0925
	0.4	0.0	0.2786	0.0753	0.3222	0.0735	0.4324	0.0718
		0.5	0.3008	0.0866	0.3461	0.0834	0.4634	0.0782
		1.0	0.3658	0.1045	0.4163	0.1003	0.5179	0.0885
	0.5	0.0	0.3094	0.0753	0.3517	0.0735	0.4622	0.0716
		0.5	0.3336	0.0862	0.3788	0.0834	0.4999	0.0777
		1.0	0.4046	0.1032	0.4123	0.0957	0.4742	0.0742
Al/Al_2O_3	0.0	0.0	0.1202	0.1017	0.1605	0.0918	0.2523	0.0833
		0.5	0.1300	0.1227	0.1716	0.1104	0.2667	0.0941
		1.0	0.1585	0.1378	0.2035	0.1268	0.3074	0.1074
	0.1	0.0	0.1229	0.1017	0.1643	0.0918	0.2589	0.0833
		0.5	0.1333	0.1219	0.1759	0.1096	0.2741	0.0937
		1.0	0.1635	0.1362	0.2095	0.1253	0.3178	0.1061
	0.2	0.0	0.1298	0.1008	0.1717	0.0915	0.2681	0.0832
		0.5	0.1409	0.1200	0.1842	0.1087	0.2851	0.0934
		1.0	0.1732	0.1335	0.2205	0.1232	0.3334	0.1046
	0.3	0.0	0.1404	0.0996	0.1819	0.0912	0.2794	0.0832
		0.5	0.1523	0.1178	0.1958	0.1081	0.2997	0.0931
		1.0	0.1871	0.1306	0.2362	0.1210	0.3546	0.1025
	0.4	0.0	0.1543	0.0985	0.1946	0.0912	0.2924	0.0833
		0.5	0.1671	0.1160	0.2107	0.1079	0.3158	0.0924
		1.0	0.2049	0.1279	0.2571	0.1177	0.3701	0.0985
	0.5	0.0	0.1714	0.0976	0.2096	0.0915	0.3067	0.0835
		0.5	0.1855	0.1145	0.2289	0.1081	0.3335	0.0911
		1.0	0.2268	0.1252	0.2708	0.0904	0.3980	0.0801

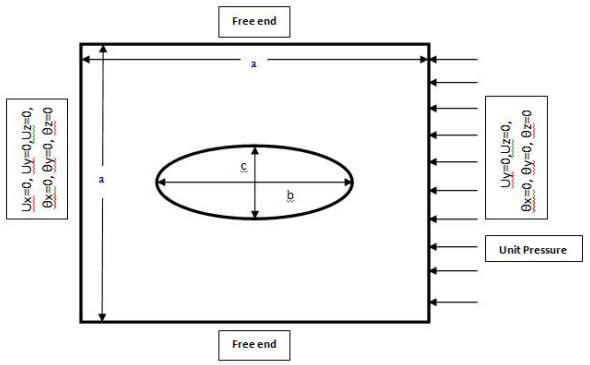

Figure 1: Geometry of elliptical cutout with dimensions (b, c) for square plate.

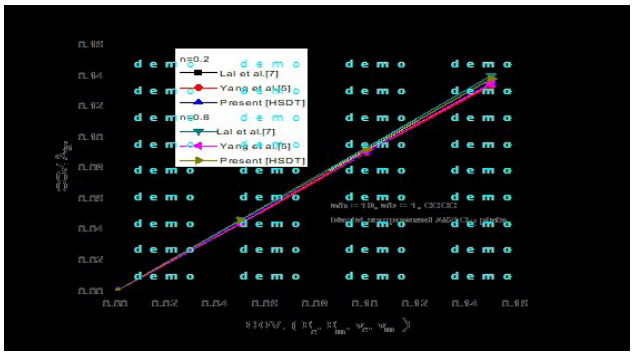

Figure 2: Comparative graph for SD/Mean Coefficient of Variations with uncertainty in material qualities, biaxial compression.

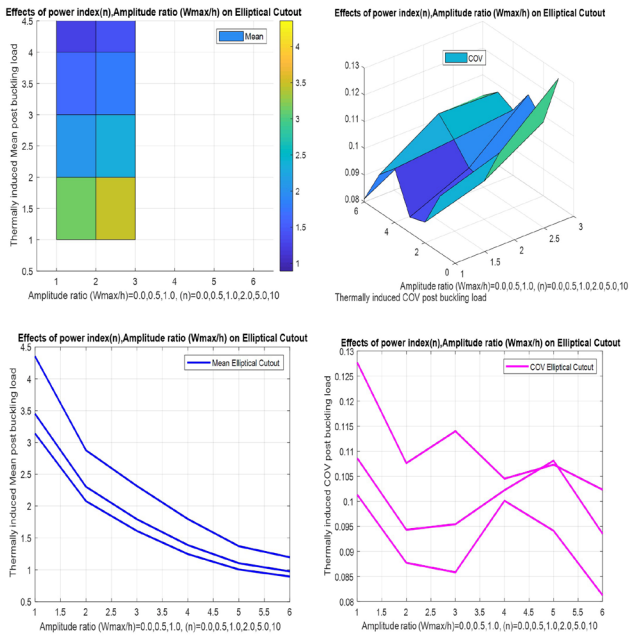

Figure 3: Effects of power index amplitude ratio on mean and coefficient of variations of elliptical cutout plate.

Conflict of Interest

The author assures no conflict of interests that are relevant to the content of this article.

Author Contributions

Conceptualization & Methodology, Formal analysis and investigation, Writing – original draft preparation, Writing - review and editing

Acknowledgement

Nil

References

1. Shen HS. 2000. Hygrothermal effects on the postbuckling of composite laminated cylindrical shells. Compos Sci Technol 60(8): 1227-1240. https://doi.org/10.1016/S0266-3538(00)00062-2
2. Shen HS. 2001. The effects of hygrothermal conditions on the postbuckling of shear deformable laminated cylindrical shells. Int J Solids Struct 38(36-37): 6357-6380. https://doi.org/10.1016/S0020-7683(01)00123-8
3. Shen HS. 2002. Hygrothermal effects on the postbuckling of axially loaded shear deformable laminated cylindrical panels. Compos Struct 56(1): 73-85. https://doi.org/10.1016/S0263-8223(01)00187-8
4. Huang XL, Shen HS. 2004. Nonlinear vibration and dynamic response of functionally graded plates in thermal environments. Int J Solids Struct 41(9-10): 2403-2427. https://doi.org/10.1016/j.ijsolstr.2003.11.012
5. Yang J, Liew KM, Kitipornchai S. 2005. Second-order statistics of the elastic buckling of functionally graded rectangular plates. Compos Sci Technol 65(7-8): 1165-1175. https://doi.org/10.1016/j.compscitech.2004.11.012
6. Wu TL, Shukla KK, Huang JH. 2007. Post-buckling analysis of functionally graded rectangular plates. Compos Struct 81(1): 1-10. https://doi.org/10.1016/j.compstruct.2005.08.026
7. Lal A, Kulkarni NM, Singh BN. 2015. Stochastic thermal post buckling response of elastically supported laminated piezoelectric composite plate using micromechanical approach. Curved Layer Struct 2(1): 331-350. https://doi.org/10.1515/cls-2015-0019
8. Pandey R, Upadhyay AK, Shukla KK. 2010. Hygrothermoelastic postbuckling response of laminated composite plates. J Aerosp Eng 23(1): 1-13. https://doi.org/10.1061/(ASCE)0893-1321(2010)23:1(1)
9. Rekha S, Tushar S, Rajendra B. Effect of various cut out on buckling analysis of laminated composite plate using FEM simulation. ELK Asia Pacific J 978-81-930411-4-7. https://doi.org/10.16962/elkapj/si.arimpie-2015.12
10. Komur MA, Sen F, Ataş A, Arslan N. 2010. Buckling analysis of laminated composite plates with an elliptical/circular cutout using FEM. Adv Eng Softw 41(2): 161-164. https://doi.org/10.1016/j.advengsoft.2009.09.005
11. Shankara CA, Iyengar NGR. 1996. A C^0 element for the free vibration analysis of laminated composite plates. J Sound Vib 191(5): 721-738. https://doi.org/10.1006/jsvi.1996.0152
12. Kleiber M, Hien TD. 1992. The Stochastic Finite Element Method. Wiley, New York.
13. Yimin Z, Chen S, Liu Q, Liu T. 1996. Stochastic perturbation finite elements. Comp Struct 59(3): 425-429. https://doi.org/10.1016/0045-7949(95)00267-7
14. Lal A, Jagtap KR, Singh BN. 2013. Post buckling response of functionally graded materials plate subjected to mechanical and thermal loadings with random material properties. Appl Math Model 37(5): 2900-2920. https://doi.org/10.1016/j.apm.2012.06.013
15. Ghannadpour SAM, Najafi A, Mohammadi B. 2006. On the buckling behavior of cross-ply laminated composite plates due to circular/elliptical cutouts. Compos Struct 75(1-4): 3-6. https://doi.org/10.1016/j.compstruct.2006.04.071
16. Wadhonkar S, Kadam K. 2017. Bucking analysis of laminated composite plates with cut-out. Int J Innov Res Sci Eng Technol 6(1):423-427.
17. Reddy JN. 1984. A simple higher-order theory for laminated composite plates. J Appl Mech 51(4): 745-752. https://doi.org/10.1115/1.3167719