Postbuckling analysis of core-corrugated sandwich FG-GRC laminated cylindrical shells subjected to external pressure

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Abstract

An analytical approximation for nonlinear stability analysis of core-corrugated sandwich graphene-reinforced cylindrical shells is presented in this paper. A homogenization model for corrugated structures is used for corrugated core layer and the governing equation system for cylindrical shells are formulated considering the von Kármán-Donnell nonlinear theory. Three-term solution form of de-flection is chosen, and the nonlinear postbuckling relation can be formulated by applying the Galerkin procedure. The result of examinations validates the effects of the corrugated core layer, graphene volume fraction and graphene distributions with different geometric ratios on the nonlinear stability behaviors of corrugated cylindrical shells.

Introduction

The stability and dynamic studies of cylindrical shells made of advanced materials have increasingly attracted the attention of many scientists around the world in re-cent years. Among those new materials, the graphene is known for its most outstanding properties such as: the high Young's modulus, the excellent conductivity, high carrier mobility at room temperature…and specially, the thermal extension, the electrical conductivity and the price of graphene are better than carbon nanotube [1].

In 2017, Shen et al. [2] presented a new material, was named as the functionally graded graphene reinforced composite (FG-GRC) in which the graphene sheets are functionally distributed in the polymer matrix to have the desired thermo-mechanical properties. Shen and Xiang [3, 4, 5] studied the postbuckling behavior of FG-GRC laminated cylindrical shells under axial compression, external pressure with thermal environments and the temperature-dependent material properties. The postbuckling equilibrium paths for the perfect and geometrically imperfect GRC laminated cylindrical shells are obtained by applying the singular perturbation technique and the Reddy's higher order shear deformable shell theory. The extended Halpin–Tsai model is employed to estimate the temperature dependent material properties of GRCs. By using the same method, Shen et al. [6] established the motion equations for the non-linear vibration of FG-GRC laminated cylindrical shells and solved these equations based on the two-step perturbation technique.

Ly et al. [7] applied the Donnell's shell theory, the three-term solution of deflection and the Galerkin method to determine the critical axial compressive buckling load expression, the postbuckling load-deflection and the load-end shortening relations of FG-GRC laminated cylindrical shells under axial compressive load surrounded by Pasternak's elastic foundation in thermal environment. Phuong et al. [8] proposed the improved smeared stiffener technique for the anisotropic stiffeners made of FG-GRC to stiffened for the FG-GRC laminated cylindrical shells. The shell is rested on the Pasternak elastic foundation and subjected to uniform external pressure and temperature change effects.

To increase the rigidity of the cylindrical shell, the core-corrugated cylindrical structure has been proposed. The buckling and vibration studies of corrugated cylindrical shell made of isotropic material have been discussed in recent years [9, 10, 11, 12]. Hung et al. [13] proposed the spiral corrugation form for the sandwich functionally graded cylindrical shells with shell-foundation interaction and formulated the governing equations for the nonlinear buckling behavior of shell.

According to the author's knowledge, the researches on the corrugated cylindrical shells made of FG-GRC are still very limited. Basing on the Donnell shell theory and the homogenization theory of Xia et al. [14], the nonlinear equations of core-corrugated sandwich GRC cylindrical shells are derived in this study. The critical buckling load and postbuckling curves are obtained by using the Galerkin method

Methodology

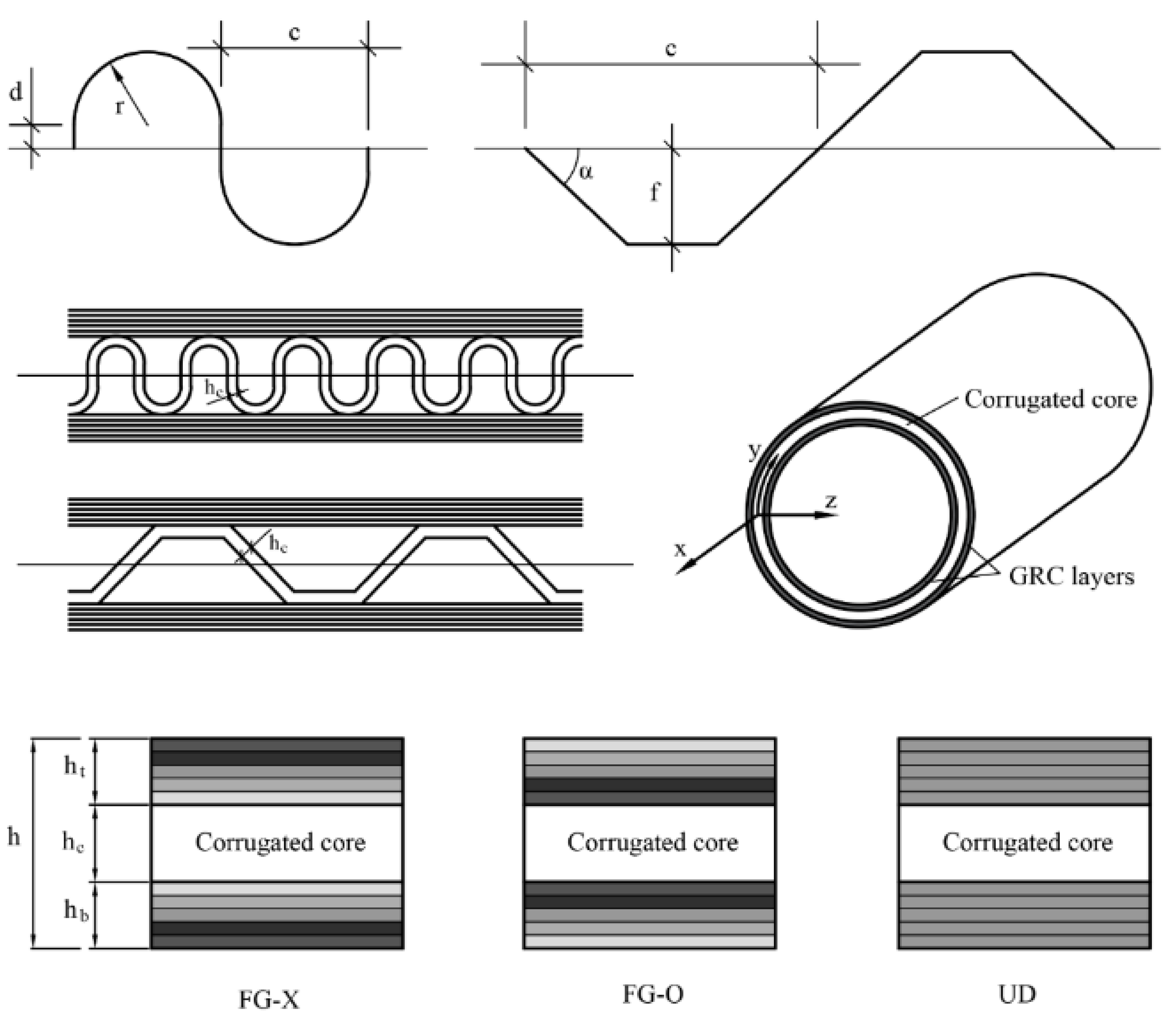

Fig. 1. Configuration of GRC cylindrical shells with corrugated core

1) **The Donnell thin shell theory with von Karman nonlinearities is used,**
2) **The homogenization technique for corrugated structures of Xia et al. [14] is applied,**
3) **The stress function is introduced,**
4) **The three-term solution of deflection is chosen,**
5) **The Galerkin method is applied,**
6) **Critical buckling loads are determined by using the bifurcation criterion.**

Results

Table 2. Critical loads of core-corrugated sandwich GRC shells (Mpa)

		Round corrugation		Trapezoidal corrugation	
		$(0)_{10}$	$(0/90/0/90/0)_S$	$(0)_{10}$	$(0/90/0/90/0)_S$
FG-X	Without core	0.1525(1,7)	0.1530(1,6)	0.1525(1,7)	0.1530(1,6)
	Solid core**	0.2412(1,6)	0.2419(1,6)	0.1890(1,6)	0.1893(1,6)
	Corrugated core	0.3529(1,6)	0.3544(1,6)	0.3529(1,6)	0.3543(1,6)
FG-O	Without core	0.0993(1,7)	0.1000(1,7)	0.0993(1,7)	0.1000(1,7)
	Solid core	0.1798(1,6)	0.1807(1,6)	0.1343(1,7)	0.1354(1,7)
	Corrugated core	0.2718(1,6)	0.2736(1,6)	0.2717(1,6)	0.2736(1,6)
UD	Without core	0.1405(1,7)	0.1410(1,7)	0.1405(1,7)	0.1410(1,7)
	Solid core	0.2325(1,6)	0.2331(1,6)	0.1812(1,6)	0.1815(1,6)
	Corrugated core	0.3449(1,6)	0.3462(1,6)	0.3449(1,6)	0.3461(1,6)

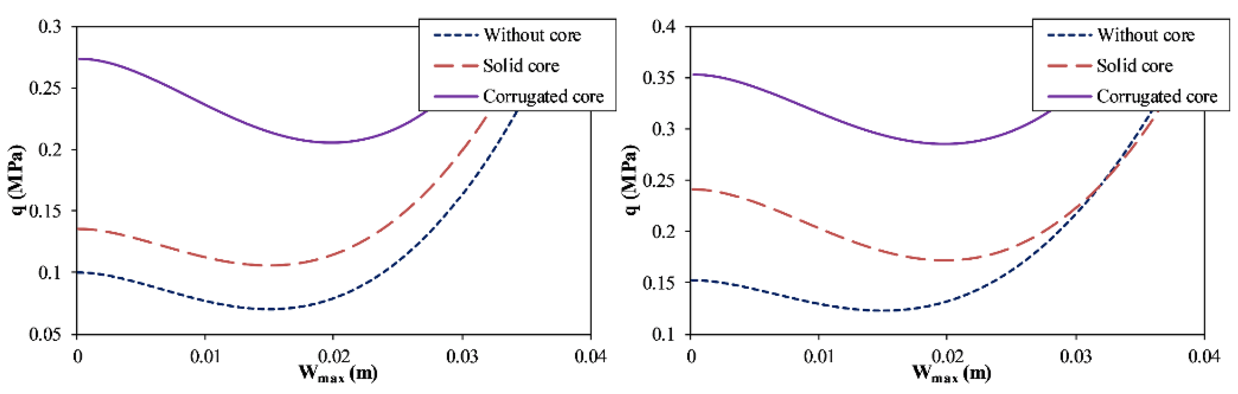

Fig. 2. Postbuckling curves of core-corrugated shells with different core types (a: round, FG-X (0)10; b: trapezoidal, FG-O (0/90/0/90/0)S)

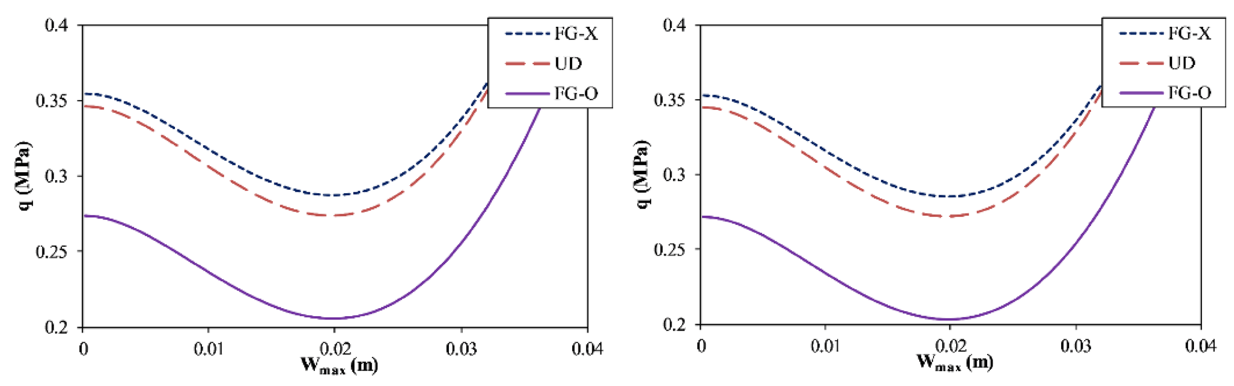

Fig. 3. Postbuckling curves of core-corrugated shells with different Graphene distributions (a: round, $(0/90/0/90/0)_S$; b: trapezoidal, $(0)_{10}$)

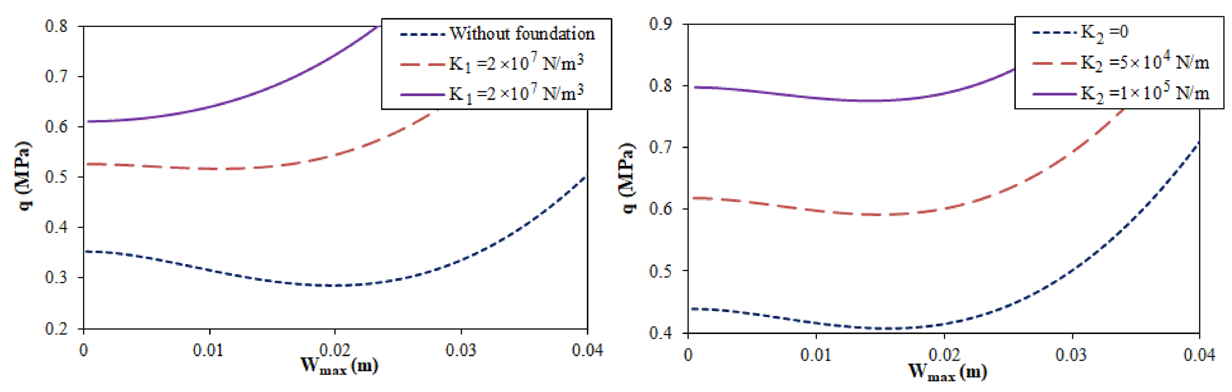

Fig. 4. Postbuckling curves of trapezoidal core-corrugated $(0)_{10}$ FG-X shells with different Pasternak parameters (a: K_2=0; b: $K_1=10^7$ N/m^3)

Conclusion

This paper presented an analytical approach for the nonlinear postbuckling behavior of cylindrical shells with corrugated core and GRC laminated face sheets under external loads. The homogenization technique for corrugated core is combined with the nonlinear Donnell theory to formulate the stability equations of cylindrical shells. Three states of buckling process and Pasternak elastic foundation are also considered. The investigated results showed the remarkable effects of corrugated core and input parameters on the nonlinear and linear stability behavior of shells.

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