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Dynamic analysis of functionally graded truncated conical shells subjected to asymmetric moving loads

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ABSTRACT

The dynamic behavior of functionally graded (FG) truncated conical shells subjected to asymmetric internal ring-shaped moving loads is studied. The material properties are assumed to have continuous variations in the shell thickness direction. The equations of motion are derived based on the first-order shear deformation theory (FSDT) using Hamilton's principle. The finite element method (FEM) together with Newmark's time integration scheme is employed to discretize the equations of motion in the spatial and temporal domain, respectively. The formulation and method of solution are validated by studying their convergence behavior and carrying out the comparison studies in the limit cases with existing solutions in the literature. Then, the influences of material graded index, radius-to-length ratio, semi-vertex angle, thickness, boundary conditions and moving load velocity on the dynamic behavior of the FG truncated conical shells are studied. In addition, the difference between the responses of the FG shells under symmetric and asymmetric loadings is compared.

1. Introduction

Functionally graded materials (FGMs) has been introduced to overcome the main drawbacks of the conventional laminated composite materials such as layer de-bonding and interface cracking [1] and consequently, improving their load-carrying capacity. The thermo-mechanical properties of these types of materials vary smoothly and continuously along specific direction(s) over the entire domain to satisfy the requirements for service in extreme environments like high temperature, high fluid pressure and strongly corrosive conditions [2].

As an important structural element, truncated conical shells made of FGMs have wide applications in chemical pipelines, nuclear vessels, fuselage structures of civil airliners, military aircraft propulsion system and other modern aerospace and defense productions. In some applications, the applied internal load on the inner surface of these structural elements may move along a certain direction. In addition, the disturbance in the internal pressure can move along their axis and consequently, it can be modeled as a dynamic moving load or moving mass problems. Hence, accurate prediction of their vibration characteristic under moving load becomes essential for engineering design and manufacture. On the other hand, in the most research works

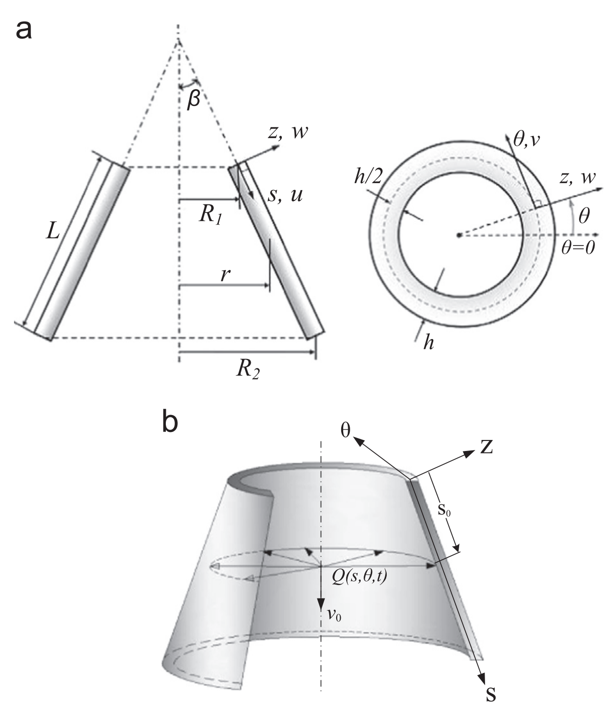

Fig. 1. (a), (b) The geometry and loading condition of FG conical shell.

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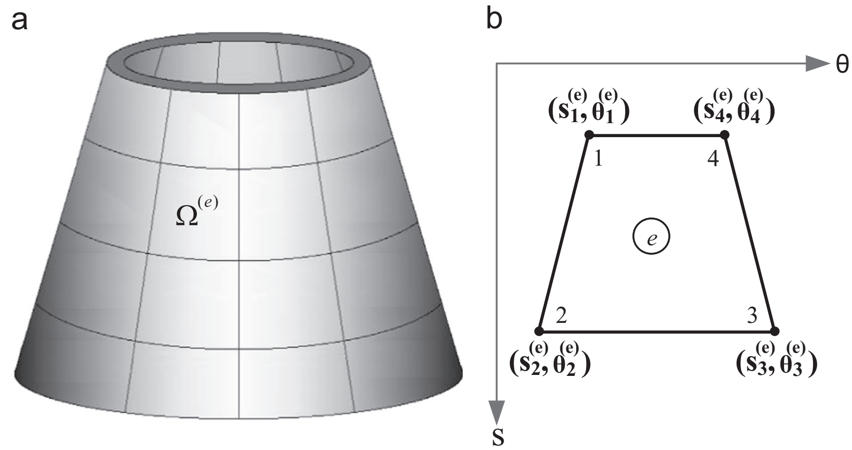

Fig. 2. (a) Discretized spatial domain of a truncated conical shell and (b) the trapezoid element.

Table 1
Convergence and accuracy of the first non-dimensional natural frequency parameter $\overline{\omega}_1$ of homogenous truncated conical shells with clamped ends ($h/R_1=0.1, h/L=0.1, \beta=\pi/6$).

m	$N_s^e \times N_\theta^e$						DQM [10]
	20 × 30	30 × 45	45 × 45	45 × 75	45 × 95	45 × 125	
0	0.9098	0.9064	0.9060	0.9060	0.9060	0.9059	0.9071
1	0.8869	0.8792	0.8791	0.8791	0.8790	0.8789	0.8675
2	0.8220	0.8104	0.8088	0.8057	0.8047	0.8043	0.8114
3	0.8082	0.8041	0.8035	0.8015	0.8012	0.8011	0.7967

Table 2
Comparison of the first non-dimensional natural frequency parameter $\overline{\omega}_1$ of homogenous cylindrical shells with clamped ends ($N_s^e \times N_\theta^e = 45 \times 95$).

m	h/L	h/R_1	Present	DQM [10]
0	0.01	0.01	0.9680	0.9679
1			0.8563	0.8562
2			0.6630	0.6626
0	0.01	0.02	0.9308	0.9306
1			0.5838	0.5860
2			0.3815	0.3811
0	0.05	0.01	0.3724	0.3723
1			0.2418	0.2413
2			0.1405	0.1361
0	0.1	0.1	1.1527	1.1523
1			1.0368	1.0363
2			0.9120	0.9111

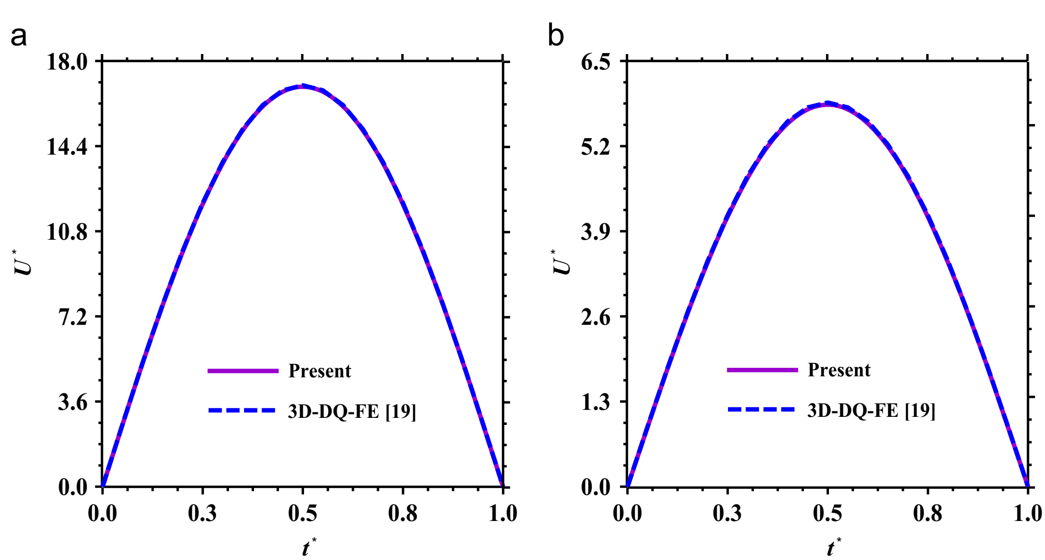

Fig. 3. (a), (b) Comparison of the non-dimensional radial displacements $U^*=((K^*/p_0h))u$of FG cylindrical shell with clamped ends subjected to dynamic pressure($E_m=223$ GPa, $\rho_m=8900$ kg/m^3, $n_1=2$, $n_2=-5.93$, $\nu_m=0.3$, $L=1$ m, $K^*=10$ GPa). (a) r_{in}=0.975 m, in r_{out}=1.025 m and (b) r_{in}=0.96 m, r_{out}=1.04 m.