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Analysis of Functionally Graded Conical Shell Structure Reinforced with Carbon Nanotubes

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Abstract- The present work deals with the free vibration analysis and buckling behavior of functionally graded nanocomposite conical shell structures reinforced with carbon nanotubes. The effective material properties of the functionally graded nanocomposite shell structures are obtained using the extended rule of the mixture by using uniformly distribution (UD) and some functionally graded distribution of single-walled carbon nanotubes (SWCNTs) in the thickness direction of the shell. In this study the nanocomposite is forming by mixing SWCNTs as a reinforced phase with the polymer as matrix phase and makes a superior quality nanocomposite material at the nanoscale level with some extraordinary material properties which provides advanced performance and service level. A suitable finite element model of functionally graded conical shell structure is developed using the ANSYS parametric design language (APDL) code in ANSYS environment. The model has been discretize using an eight node shell element. The solution is obtained for fundamental natural frequencies and deformation of the composite shell. The effects of various geometric parameters, CNT volume fraction, boundary conditions and material properties are presented and discussed.

Keywords— Conical shell structures, CNTs based polymer nanocomposite, various CNT distributions, functionally graded material (FGM), free vibration, buckling analysis.

I. INTRODUCTION

Basically a composite material is a combination of two constituents one is called reinforcing phase (or embedded phase) and the other in which this reinforcing phase is embedded known as matrix. The matrix phase materials are generally continuous and the reinforcing phase are discontinuous or dispersed phase.

The reinforcing phase serves to strengthen the composite materials, this phase may be in the form of particles, fibers or flakes. Various varieties of reinforcing materials used in composite structures are glass fiber, graphite (carbon), asbestos, jute, sisal, boron kevlar 49 and whiskers, as well as chopped paper and synthetic fibers. There are three basic types of matrix materials polymers, metals or ceramics. The two chief purposes of the matrix are binding the reinforcement phases (embedded phase) in place and deforming to distribute the stresses between the constituent reinforcement materials under some applied forces. Examples of composite materials include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc. An increasing number of engineering structural designs, especially in the automobile, aerospace and civil engineering structures are extensively utilizing various types of fiber composite laminated structures such as beams, plates and shells.

The laminated orthotropic shell structures belong to the category of composite shell. In recent years the use of laminated composite shell structures is increased for high performance structures such as wind turbine blades, fuselages of aircraft, ship and boat hulls etc. The main important factor in the analysis of the laminated shell structures is its individual layer properties, which may be made of orthotropic, isotropic or anisotropic materials. The primary function of a laminated shell is to transfer the loads from the edges of one layer to another. A thin shell is defined as a shell which has very small thickness as compared to its diameter, about 20 times smaller than its diameter. Laminated shells are widely used in various engineering fields because of its light weight and high strength like in structural engineering, power and chemical engineering, architecture and building, vehicle body structures, composite construction, armour, submarines etc.

II. LITERATURE SURVEY

(i) Fibrous Composites

Fiber reinforced composite materials are composed by embedding the fiber materials in matrix material. Mainly fiber composites has two types first is random or short fiber reinforced composite and the other is continuous or long fiber reinforced composites. In random fiber reinforced composites the fiber materials is in the short discontinuous forms and are arranged in random order throughout the matrix material. In continuous or long fiber reinforced composites the long fiber is used in matrix material along its length or width according to the requirement.

(ii) Particulate composites

The particulate composites are composed by embedding or distributing the particle in the matrix. These particles may be in the form of flakes or powder in the matrix material.

(iii) Flake composites

Flake composites are consist of flat flakes as reinforcements which embedded in the matrix material. Some types of flake materials are glass, aluminum, mica and silver.

(iv) Filler composites

Filler composites are result from addition of filler materials in plastic matrices to replace a particular part of the matrix also to change or enhance the properties of the composite materials.

(v) Laminar composites

A laminar composite is a plane or curved layer of unidirectional fibers in the matrix material. Sandwich structures fall under this category.

III PROBLEM IDENTIFICATION

• Static and free vibration problems are considered to examine the variation in thermo elastic behavior of functionally graded material (FGM) beam with pure ceramic beams or pure metal.

• Their major drawback is however represented by the effects of different loads and pressures impact load, crippling loads repeated cycle stress etc.

IV. RESEARCH OBJECTIVES

• To evaluate the material properties of FG-CNTRC conical and doubly curved (catenoidal) shell structures using the extended rule of mixture by using UD and some other types of distributions of CNT volume fraction.

• Develop a mathematical model for functionally graded carbon nanotubes based composite shell structures under the effects of compressive loads using the ANSYS parametric design language (APDL) code to develop the model in the environment of ANSYS software.

• To evaluate the effects of buckling load and free vibration on the functionally graded carbon nanotubes shell structure is based on UD, FG-V, FG-X and FG-^ with the help of geometrical parameters of the different layers of functionally graded carbon nanotube composite shell.

V. METHODLOGY

Consider a truncated conical shell made of carbon nanotube reinforced composites (CNTRCs) in which the distribution of carbon nanotubes (CNTs) is graded along the thickness direction of FG-CNTRCs. Four different types of distributions of CNTs are considered along the shell thickness directions which are shown in Figure 1. In the first case of distribution, the CNTs has a uniformly distribution through the direction of shell thickness, which is referred to UD type as shown in Figure 1(a). In the second case of distribution, the distribution of CNTs have a mid-plane symmetry and both the inner and the outer surfaces are rich CNTs, which is referred to FGX type as shown in Figure 1(b). In the third type of distribution, the outer surfaces have lean CNTs and has rich matrix, whereas the inner surface is CNTs-rich. This type of distribution is known as type distribution as shown in Figure 1(c). In the last case of distribution, the distribution of CNTs are opposite of third type, in which the inner surface is matrix-rich and the outer surface is CNTs-rich and known as FG-V type of distribution as shown in Figure 1(d).

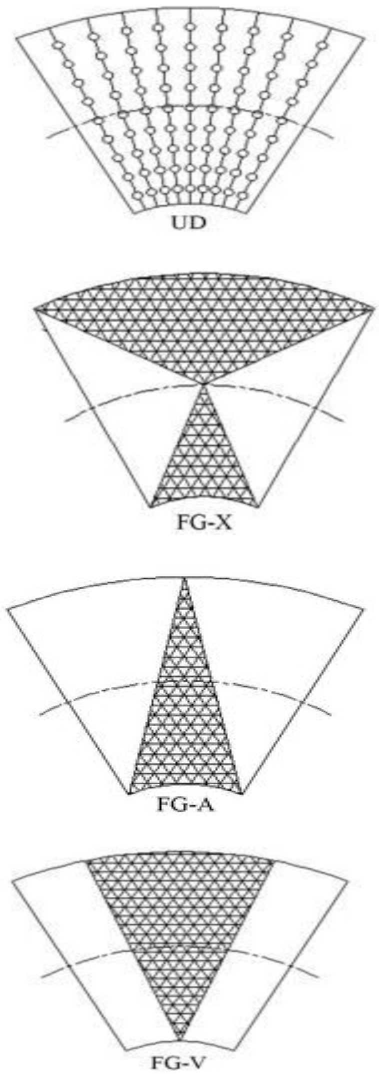

Figure 1: Different Types of Distribution of CNTS

In order to model the effects of the carbon nanotubes on the overall properties of the nanocomposite conical shell structure, the extended rule of mixture is used as a convenient and simple micromechanics model. According to this rule, the effective Young's modulus and shear modulus of FG-CNTRC shell structures can be expressed as

$$E_{11} = \eta_1 V_{CNT} E_{11}^{CNT} + V_M E^M$$

$$\frac{\eta_2}{E_{22}} = \frac{V_{CNT}}{E_{22}^{CNT}} + \frac{V_M}{E^M}$$

$$\frac{\eta_3}{G_{12}} = \frac{V_{CNT}}{G_{12}^{CNT}} + \frac{V_M}{G^M}$$

Where, E_{11}^{CNT} , E_{12}^{CNT} = Young's modulus of CNTs

G_{12}^{CNT} = shear modulus of CNTs

E^M = Young's modulus of matrix,

GM = shear modulus of matrix,

V_{CNT} = volume fraction of CNTs,

V_M = volume fraction of matrix,

η1 η2 η3= efficiency parameters of CNTs.

In addition, the relationship between the volume fraction of CNT (V_{CNT}) and volume fraction of matrix (V_M) is given by:

$V_{CNT} + V_M = 1$

The material properties of the FG-CNTRC conical shells vary smoothly and continuously in the direction of the shell thickness. Similarly, in order to evaluate the various CNT distributions effects on the free vibration characteristics of a FG-CNTRC conical shell, different types of material profiles through the shell thickness are considered. In this present work, we are assuming only linear distribution of the CNT volume fraction for the various types of the FG-CNTRC conical shell that can easily be achieved in practice and given by

UD: $V_{CNT} = V_{CNT}^*$

FG-V: $V_{CNT} = V_{CNT}^* \left(1 - \frac{2z}{h}\right)$

$FG-\Lambda$: $V_{CNT} = V_{CNT}^* \left(1 + \frac{2z}{h}\right)$

FG-X $V_{CNT} = V_{CNT}^* \left(\frac{4|z|}{h}\right)$

VI. RESULTS AND ANALYSIS

Based on the above formulation the free vibration analysis and buckling behavior of functionally graded nanocomposite conical shell is carried out by using ANSYS (APDL code) and some of the results are presented here. The material properties of matrix material are V^M = 0.34, ρ^M = 1150 kg/m3 and E^M =

2.5Gpa at environment temperature (300oK). The material properties of single walled carbon nanotube (SWCNTs) are E_{11}^{CNT}= 5.6466 TPa, E_{22}^{CNT} = 7.0800 TPa, G_{12}CNT = 1.9445 TPa, ρ = 1440 kg/m3 and v CNT=.175 mixes with the polymer at 12%, 17% and 28% distributions of CNTs.

Table 1: CNT Efficiency Parameters for Different CNT Volume Fraction

CNT EFFICIENCY PARAMETERS			
V_{cnt}	η_1	η_2	η_3
0.12	0.137	1.022	0.715
0.17	0.142	1.626	1.138
0.28	0.141	1.585	1.109

To analyze the vibration and buckling effects on the FG nanocomposite conical shell structures, two types of boundary conditions are considered, namely simply supported boundary condition and clamped-clamped boundary condition. The below equation describes the boundary condition for both the cases

Simply supported boundary condition:

u = v = w = θy = 0, Mx = 0 at x=0,

u = v = w = θx = 0, My = 0 at y=0,

Clamped-clamped boundary condition:

u = v = w = θx = θy = 0, at x=0,

u = v = w = θx = θy = 0, at y=0,

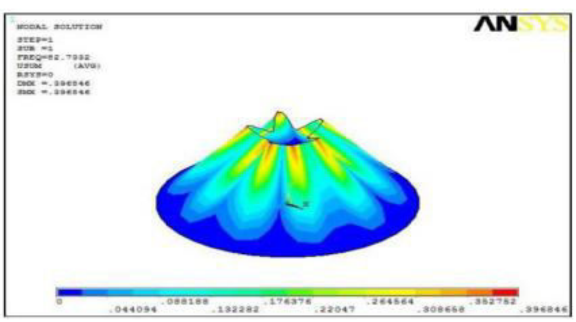

Figure 2: Mode Shapes for Conical Shell (Mode Shape 1-2)

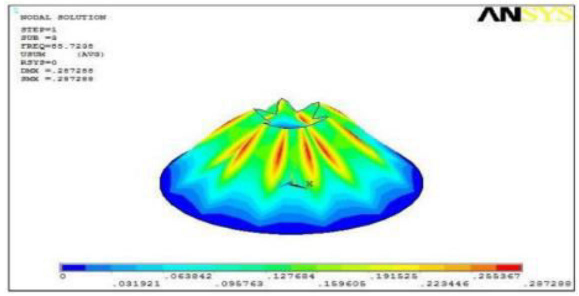

Figure 3: Mode Shapes for Conical Shell (Mode Shape 3-4)

IV. CONCLUSIONS

The present work enables to arrive at the following important conclusions: From the above solutions, the present work has been investigated. The vibration behavior and buckling analysis for the functionally graded carbon nanotube reinforced conical shell and for doubly curved (catenoidal) shell has been carried out by using the extended rule of mixture for the FG-CNTRC shell structures and considering the different types of distributions of CNTs. From the results, it is found that the buckling load parameter is maximum for the FG-Λ and minimum in the case of FG-V type of CNT distribution. The buckling behavior and fundamental frequencies has been obtained by using the ANSYS parametric design language (APDL) code in the ANSYS software. The fundamental frequencies have been carried out by using the Block-Lanco's method in ANSYS environment. It is noticed that the fundamental frequencies and buckling load parameter increases with the increase of carbon nanotube volume fraction which implies that there is increase of stiffness of the FG-CNTRC shell structures with decrease in deflection.

The present work is based on the analysis of free vibration and buckling behavior of functionally graded material based carbon nanotube reinforced nanocomposite shell structures under the effect of compression load.

• To analyze the vibrational behavior and buckling analysis, the present work can be extended on the basis of temperature dependent material properties and thermo mechanical loading conditions.

• The present work can be extended to evaluate the forced vibration for nanocomposite functionally graded carbon nanotube reinforced shell structures.

• On the basis of this work, we can investigate the vibrational behavior for different geometric shell structures such as plate, spherical, hyperboloid, cylinder etc.

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