BUCKLING ANALYSIS OF FUNCTIONALLY GRADED GRAPHENE REINFORCED COMPOSITE PLATE WITH A CIRCULAR CUT-OUT

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Abstract - *Buckling analysis of functionally graded graphene reinforced composite plates with a circular cutout is investigated. It supposes that the distribution types of graphene reinforced composites are uniformly distributed in the thickness direction. The Graphene platelets (GPLs) weight fraction shows a layer-wise change along the thickness direction with GPLs uniformly dispersed in the polymer matrix in each individual layer.*

The mechanical properties of the composites, including Young's modulus, mass density and Poisson's ratio, are determined by modified Halpin-Tsai model and rule of mixture. After a convergence and validation study to verify the present analysis, a comprehensive parametric investigation on the influences of the weight fraction and geometric parameters of graphene reinforced composite plate is conducted.

A simply supported functionally graded graphene reinforced composite square plate with different volume fractions, width-to-thickness ratios and cut-out ratios are investigated. The ANSYS WorkBench software is to be used to find the critical loads of the graphene plate when it subjected to uniaxial compression is studied. It is found that the addition of a small amount of GPLs significantly increases the critical buckling load of the graphene reinforced composite plate.

Key Words: **Composites**

1. INTRODUCTION

A. Functionally Graded materials(FGM)

The concept of FGM was first considered in Japan in 1984 during a space plane project.In recent years this concept has become more popular in Europe, particularly in Germany.A new class of composite materials known as functionally graded materials (FGMs) has drawn considerable attention of the scientific community. FGMs exist in nature like wood, bamboo, etc. Even human bones are also FGM. The aircraft and aerospace industry and the computer circuit industry make wide use of FGM that can withstand very high thermal gradients. This is normally achieved by using a ceramic layer connected with a metallic layer.

Functionally graded materials (FGM) can be obtained by layered mixing of two materials of different mechanical properties with different volume ratio by gradually changing from layer to layer such that the first layer has only a few particles of second phase and the last has maximum volume ratio of the first phase. In FGMs, the different micro-structural phases have different functions. The overall FGMs attain the multi-structural status from their property gradation.

Functionally graded materials belong to a class of advanced materials characterized by the variation in properties as the dimension varies (usually along the thickness). The overall properties of FGM can be varied according to our needs, thus one of the main advantages of such a material is that it can be tailored specifically for serving a particular function that makes it unique from any of the base materials used in its synthesis.The FGMs can be designed to reduce thermal stresses and take advantage of the corrosion and heat resistances of ceramic and the mechanical strength, good machinability , high toughness and bonding capability of metals without severe internal thermal stresses, also exhibit higher fracture resistance parameters resulting in higher toughness due to bridging of cracks in a graded volume fraction.

They are also defined as high performance, microscopically anisotropic materials engineered with great precision in gradients of composition and structure to adapt to various specific purposes and to have definite properties in preferred orientation. The desired mechanical properties of FGMs i.e. Poisson's ratio, Young's modulus, shear modulus and material density can be obtained in a preferred direction through the variation of volume fractions of the constituent materials spatially.

FGMs find applications in aerospace, automobile, medicine, sport, energy, sensors, defense, and optoelectronics, Aerospace functionally graded materials can withstand very high thermal gradient thus makes it suitable for use in structures and space plane body, rocket engine components.

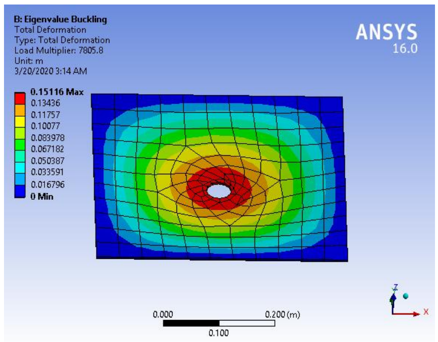
B. GRAPHENE

Graphite of which the term was derived from the Greek word “graphein” (to write) in, is a layered planar structure composed of carbon atoms that are arranged in a honeycomb lattice. The separation between carbon atoms in the lattice is 0.142 nm, and the distance between planes is 0.335 nm in graphite structure. In graphite, isolated single layer that is composed of sp2 hybridized carbon atoms is called graphene. The term of graphene originates from the combination of graphite and suffix –ene that is earlier used in the nomenclature and terminology of polycyclic aromatic hydrocarbons. The possibility of wrapping up graphene into 0D fullerenes, rolling it into 1D carbon nanotubes (CNTs) and stacking of it into 3D graphite makes graphene the central building block of all graphitic materials

ANALYSIS

The step by step procedure for buckling analysis of a plate with a cutout by using ANSYS Work bench software is as follows

- SStart Menu > ANSYS 16.0 > Work bench 16.0
- IIn the toolbox > Analysis systems menu drag Static Structural into the project schematic window
- SHave your workbench project
- Double-click Engineering Data to open the Engineering Data Tab
    - EEnter the properties of material properties > Enter > ok
    - RRight Click on Geometry in the project schematic window>Click on New DesignModeler Geometry to open the DesignModeler window
    - IIn the Design Modeler Window > Click XY Plane
    - CChange the units to millimeters
    - CClick on the Sketch Tab of the Tree Outline Menu> A click on rectangle in the Sketching Toolbar menu>Draw a rectangle in the Graphics Window
    - CClick on dimension tab in the Sketching Toolboxes> click general
    - DDimension the Rectangle >Now click on the upper edge of the rectangle and drag the dimension label out to your desired location> Change the dimension of element to desired values.
    - CClick on the circle icon in the Sketching toolbox Draw tab> select circle
    - DDraw a circle inside of the rectangle> enter the circle dimensions in dimension tab
    - NRow click generate>The sketch should change color>Save the project and close Design Modeler
    - OOpen the Modeler >Double click on Model in the Project Schematic Window>Model Geometry>Click on Mesh in the project outline >Right Click on Mesh and select Method
    - IIn the Details of Automatic Method Menu click geometry, select the plate to the right, then click apply>select Quadrilateral dominant>For Free Face Mesh Type select All Quad>now set an approximate element size>Right click mesh and select sizing> Change element size to desired value >Right click on mesh and select Generate Mesh
    - AApply Boundary Conditions (I.e. loads and constraints) > Apply the load. Right click on Static Structural an select Insert > Force > Apply Unit force on two opposite edges> Apply
    - RRight click on Static Structural an select Insert > Displacement >Select the edges of the plate >Click Geometry > Apply j
    - CChange the Z-component displacement to 0 (leave the X and Y-components free)
    - TTo avoid rigid body motion on XY plane add couple of more displacements, select displacements > select vertex > select two corner points > Change the Y-component displacement to 0 (leave the X and Z-components free) > select geometry > Apply
    - SSelect the one of the corner node point > change the X-component displacement to 0 (leave the Y and Z-components free).
    - DDrag and Drop the Linear/Elastic Buckling on solution and double click on model
    - CClick on solve without adding any solution
- RRight click on Linear Buckling > Insert > Select Total Deformation >click on solve and you will see load multiplier on left side and finally close linear buckling



RESULTS AND DISCUSSIONS

In the present investigation, buckling of functionally graded graphene reinforced composite plate with a circular cut-out is studied for uniaxial compression. The results are presented for functionally graded graphene reinforced composite plate for simply supported boundary condition.

In the present investigation the following material properties are used.

1) For poly methyl methacrylate (PMMA) matrix

Young's modulus = 3.00 Gpa

Density = 1200 kg/m^3

Poisson's ratio = 0.34

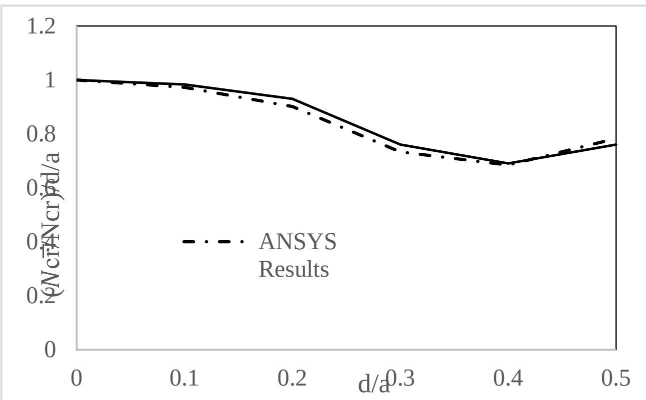
Thermal expansion coefficient = 60x10^-6/K

2) For Graphene the properties are varying with change in volume fraction and type of distribution along the thickness.

COMPARISON AND VALIDATION OF RESULTS:

In order to validate the accuracy of the present formulations, the following comparison studies are carried out,

1) The critical buckling load has been listed in Table 7.1 for a simply supported isotropic plate subjected to uniaxial compression and different width-to-thickness ratios. The ANSYS software results are compared with the theoretical values.



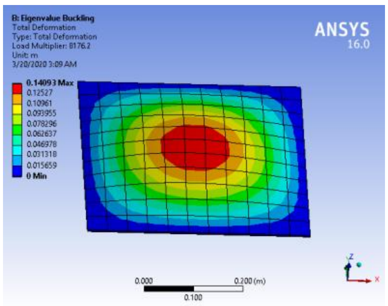
Comparison of a simply supported isotropic plate Theoretical results with Ansys software results

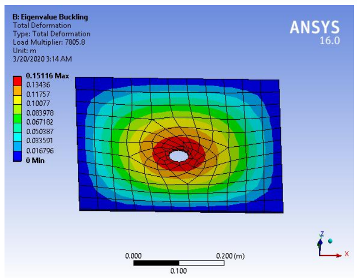
2) Uniaxial compression of simply supported isotropic plate with a central circular cutout is compared with reference

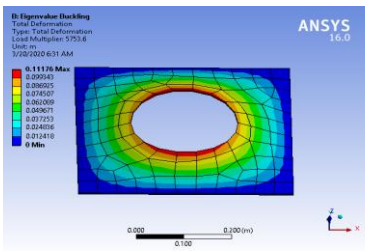
a/h	ANSYS SOFTWARE RESULTS	THEORETICAL RESULTS
10	7.749	7.592
20	62.04	60.736
30	120.97	118.62
40	283.65	280.34
50	966.36	949
100	7749.81	7592

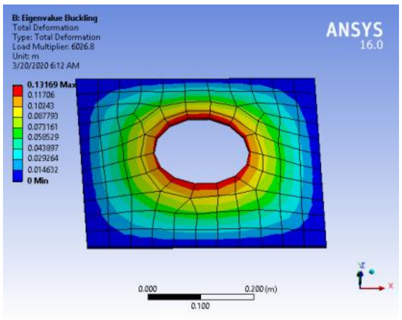
Comparison of simply supported isotropic plate with circular cut-out

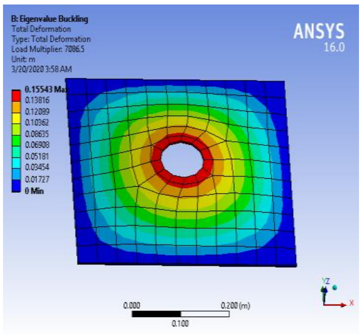
3) Buckling of functionally graded graphene reinforced composite plates for simply supported boundary condition. The critical load obtained using the ANSYS software are compared with those











CONCLUSION

In the present investigation buckling analysis of functionally graded graphene reinforced composite plate with a circular cutout is studied using the ansys workbench software. The results are presented for the variation of critical load of functionally graded graphene reinforced composite plate with different cutout ratios, volume fractions and width-to-thickness ratio for simply supported boundary condition is studied. From the results the following conclusions are observed

1. The critical load of simply supported square plate decreases with increase in cutout ratio.
2. The critical load of simply supported square plate increases with increase in width-to-thickness ratio.
3. The critical load of simply supported square plate decreases with increase in volume fraction.

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