Review on Investigation of Nonlinear damped vibrations of a hybrid laminated composite plate subjected to blast load

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Abstract- *The work is dedicated to the calculation of the overall elastic properties of matrix composite materials containing two different populations of inclusions (three phase hybrid composites). The application of the well known Mori–Tanaka method or self-consistent effective medium method to the solution of this problem gives overall elastic moduli tensors of such composites that do not have the necessary symmetry (the symmetry with respect to the first and second pairs of indices). In this work, a new version of the effective field method that takes into account specific features of the microstructure of three phase composites is developed. In this version, the field that acts on every inclusion in the composite is assumed to be different for inclusions of different populations. It is shown that the modified effective field method gives a correct symmetry of the overall elastic moduli tensors of three phase composites. The method allows us to describe the influence of the peculiarities in spatial distributions of inclusions on the overall elastic constants. The cases of media containing infinite cylindrical fibers and thin ellipsoidal disks or spherical pores are considered. Various boolean type probabilistic models of random sets of such inclusions are proposed and the elastic moduli tensors of the corresponding three phase composites are obtained and analyzed. It turns out that these tensors strongly depend on statistical properties of the random fields of inclusions. It is shown that for two phase composites, the Mori–Tanaka method is a particular case of the effective field method. In the case of three phase composites, the formulas of the Mori–Tanaka method follow from the equations of the effective field method if a general property of the symmetry of cross-correlation functions of different populations of inclusions is violated. As a result, the overall elastic moduli tensors obtained by Mori–Tanaka method lose their natural symmetry.*

Keywords- Matrix composites, Inclusions, Hybrid structures, Elastic properties, Statistical models.

I. INTRODUCTION

As long as there is development in the field of aerospace, automobile, healthcare, electronics and consumer industry the demand for new materials will never seize. The demand for new materials has controlled to continuous research and development of new techniques to satisfy the requirements.

The reinforcements can be particles or fibres of size of few nanometers. The nanocomposite has a wide range of materials from 3-D metal matrix composites, 2-D combination composites and nano-wires of small dimension representing variations of nano reinforcements. Using nanoscale reinforcements was introduce built a nanocomposite using polyimide and organophilic clay. The nanocomposite formed had twice the tensile modulus as compared to neat polyimide with just 2% volume fraction of nano reinforcement. Nanocomposites have gained a wide popularity among researchers. Researchers have discovered that the properties of the nanocomposite are better when compared to the individual components of the composite. Properties such as increased tensile strength, increased thermal conductivity are observed.

II LITERATURE REVIEW

In 2014, Suleyman Başturka et al [1] in this study, the Nonlinear damped vibrations of a hybrid laminated composite plate subjected to blast load, In this study, the nonlinear dynamic response of a hybrid laminated composite plate composed of basalt, Kevlar/epoxy and Eglass/ epoxy under the blast load with damping effects has been investigated. The von Kármán type of geometric nonlinearities are taken into account and the rectangular composite plate is assumed to be simply supported on all edges. The Galerkin Method is used to obtain the nonlinear differential equations in the time domain, and those equations are solved by Finite Difference Method.

Parametric studies are conducted. The influences of some parameters such as damping ratios, aspect ratios and different peak pressure values have been investigated.Hybrid laminated composite plates can offer better mechanical properties than conventional composite plates composed of same materials. Hybrid composite plates will become more favorite structural materials due to their high performance in order to use in various engineering applications such as space station structures, aircraft, automobiles and submarines. In order to investigate the dynamic behavior of hybrid composite plates, there are some studies in the literature.

In 2014, Raifee et al [2] estimated mechanical properties of epoxy based nanocomposite with SWCNT, MWCNT and graphene platelets were compared for weight fractions of 0.1%. The material properties measured were Young’s modulus, fracture toughness, ultimate tensile strength. The tensile strength of graphene based nanocomposites showed better properties as compared to CNT based nanocomposites.

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They evaluated the properties of nanocomposite for different nano fillers. The nanocomposites exhibited greater strength, stiffness and fracture toughness. They found that DWCNT based nanocompositedisplayed greater fracture toughness.

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In 2015, Seidel et al [4] estimated actual elastic properties of composites consisting of aligned SWCNTs or MWCNTs using Mori-Tanaka method. The effects of an interphase layer between CNTs and the polymer is also investigated using a multi-layer composite cylinders approach.

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Liu and Chen [6] estimated effective elastic properties of the nanocomposite are evaluated using continuum modeling and finite element method. The extended rule of mixture is used to definethe properties of the continuum model.

III HYBRID COMPOSITES

The important properties that are desired from any composite are strength, stiffness, ductility, toughness, damping, energy absorption, thermal stability and low weight. With conventional materials it is not possible to get all the desired properties, but with composite materials we can tailor the properties of material as per our needs. By using reinforcements of nanoscale in polymer composites there has been tremendous increase in mechanical properties as compared to neat polymer matrix. Hybrid compounds are new type of three phase composites which have reinforcements of nano scale in addition to conventional reinforcing fiber in matrix or by growing reinforcements of nano scale on the surface of fiber. R.C.L. Dutra et al [10] defined hybrid composites as composites containing of different fibers. The main purpose of using hybrid composites is it increases the matrix dominated properties.

IV CLASSIFICATION OF PLATES

Plates can be classified into two types: [11].

- Thin plates.
- Thick plates

- **A thin plate can further be classified as:**

Plates with large deflection Plates with small deflection If the deflection of a plate when subjected to loading is less than or nearly equal to thickness, then the plate is said to have small deflection. The necessary assumptions for developing theory for plates having small deflection are[12]:

The middle plane does not deform on loading. Point on the plate initially normal to middle plane remain normal to middle plane even after loading. The stresses in the thickness direction can be neglected[13].

- **Thin plates with large deflection**

If the deflections of the plate are large when subjected to lateral loading as compared to thickness, then the plate is said to have large deflection. When plate is loaded mid plane strains are developed. In plates with small deflection it is normally neglected, as a result the stresses are also neglected. [14]But if deflections are large as compared to thickness, the strains developed are large. So stresses cannot be neglected. In this case we obtain nonlinear equations and analysis becomes complicated.

Thick plate

The above approximations for thin plates are not applicable. Thick plate theory must be used[15]. The thick plate theory contains 3-D theory of elasticity and calculation of stresses is quite complicated.

Difference between plate and shell

The major difference between plates and shells can be observed under the action of loading. When a plate member is subjected to lateral load, equilibrium is possible by the action of bending and twisting moments[15]. In shells, when it is subjected to lateral loading, equilibrium is possible by membrane stresses which act parallel to tangential plane at a point on middle surface and are distributed uniformly over the thickness of shell. Plates are plane member and shells are rounded structural members.

Damping in composites

Damping is a very essential parameter for vibration control, noise reduction, stability of system, fatigue and impact resistance [16]. The damping in fibre reinforced composites is different from that of metals. The various forms of energy dissipation are Damping behaviour of matrix material.The major contribution to damping is from matrix, the damping of fiber must also be included for calculation of damping. [17]Damping behaviour of interphase Interphase is the region between matrix and fiber. The type of interphase plays an important role in damping. The interphase can be weak or strong. Damping due to damage Frictional damping due to delamination. Damping due to energy dissipation of cracked fibers or cracks inmatrix. Visco plastic damping At higher amplitudes of stresses, there is non-linear damping due to presence of high stress and strain.

Impulse response of linear time invariant system (LTIS)

Impulse force is a force which acts on the system for very short amount of time. [18]Knowing the impulse response of LTIS we can obtain by superposition the response of the same system to any input provided the input conditions are zero in all cases. Unit impulse input has very short intervals of time but very large amplitude and hence the effect of the behaviour of the system under study is not negligible. Ex: Ball hitting the cricket bat, the ball is acted upon by very large force for a short duration of time.

IV MOTIVATION

Hybrid composites are new type of three phase compounds which increase the matrix dominated properties. The hybrid composite that is to be exhibited here consists of nanocomposite matrix and continuous long carbon fibers. The nanocomposite is made up of randomly distributed CNTs and polymer matrix. The nanocomposite is modeled using Mori-Tanaka method. The hybrid composite can be exhibited using mechanics of materials approach. As the mobility of system goes on increasing, exhibiting damping for such systems becomes complicated. Rayleigh damping model has been used to perfect such multi degree of freedom systems. Further investigation has been carried out by assuming suitable damping ratios for first mode and last significant mode where mass is proportional to damping. Impulse response of the system has been carried out and a comparative study has been made to know effect of damping in systems by varying the volume fractions of carbon fiber and CNTs.

V OBJECTIVE

1. Material modelling and material characterization.
2. Nanocomposite has been modeled exhausting Mori – Tanaka method.
3. Hybrid composite containing of carbon fiber and nanocomposite matrix has been modelled using mechanics of materials approach.
4. 8 noded shell element formulation.
5. Mindlin theory of plates and shells has been used to perfect shell.
6. Modelling damping and Impulse response.
7. Rayleigh damping has been used to model the damping of MDOF system.
8. Impulse response of the system has been carried out using the state space model.

VI MATERIAL MODELING

The material modeling is divided in two phases:

- CNT based nanocomposite modeling.
- Hybrid composite modeling.

The nanocomposite consists of randomly dispersed straight MWCNT as reinforcements and epoxy as matrix. As the CNTs are randomly distributed the nanocomposite can be modeled as isotropic material[19]. The property of nanocomposite is estimated using the Mori – Tanaka method. Assuming perfect bonding between fiber and nanocomposite the hybrid composite can be exhibited similar to conventional composite using mechanics of materials approach.

- CNT bases nanocomposite modeling

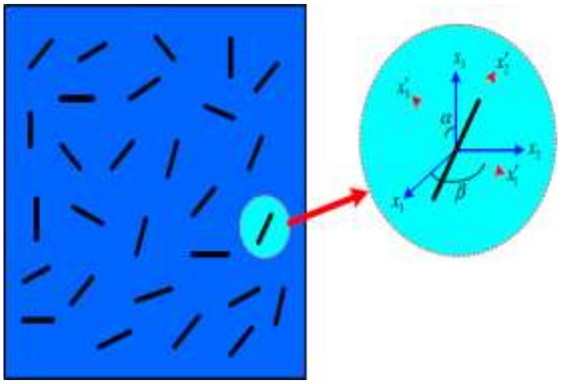
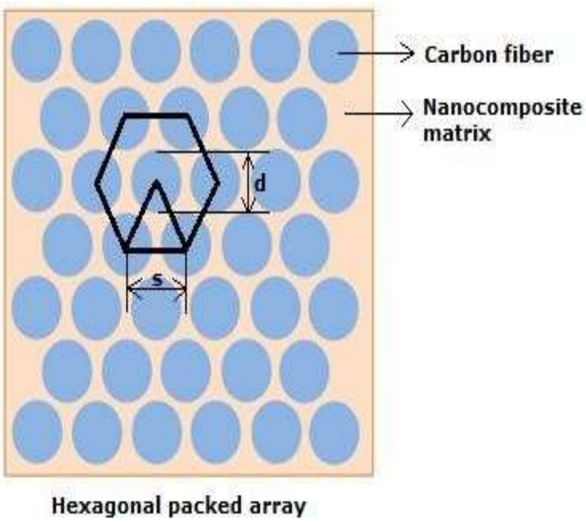


Fig.1 shows a RVE of randomly distributed CNT in epoxy matrix.



The Mori – Tanaka method was used to estimate the elastic properties of the randomly dispersed MWCNT in matrix[21].

Fig.2 shows a hexagonal RVE of hybrid composite consisting of carbon fibers dispersed in nanocomposite matrix.

Using the above considered nanocomposite properties, the properties of the transversely isotropic hybrid composite can be evaluated by the formulation of Kundalwal and Ray for fuzzy fiber[20]. Assuming perfect bonding between carbon fiber and nano compostie, the normal strains in hybrid composite, carbon fiber and nanocomposite are equal along the fiber direction and the transverse stresses in the same phase are equal along the direction transverse to the fiber from is of field conditions.[22] Using rules of mixture one can express the longitudinal and transverse stresses and strains in terms of volume fractions of nanocomposite and carbon fiber.

VII CONCLUSIONS

Strength properties were also evaluated using Direct Micromechanics method and variation with volume fraction was also studied. Longitudinal tensile strength like the longitudinal modulus largely depends on the volume fraction of reinforcement and follows a linear trend. Although, longitudinal compressive strength was evaluated using similar methods, the accuracy of the data is still questionable. This is because, phenomena like micro-buckling and instability of fibers which largely govern the compressive strength, have not been taken into account.

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