Structural Engineering and Mechanics, *Vol. 84, No. 6 (2022) 783-798*
https://doi.org/10.12989/sem.2022.84.6.783

Thickness stretching and nonlinear hygro-thermo-mechanical loading effects on bending behavior of FG beams

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(*Received September 23, 2021, Revised November 12, 2022, Accepted December 6, 2022*)

Abstract. In this paper, the nonlinear vibration behavior of the spiral stiffened multilayer functionally graded (SSMFG) cylindrical shells exposed to the thermal environment and a uniformly distributed harmonic loading using a semi-analytical method is investigated. The cylindrical shell is surrounded by a nonlinear viscoelastic foundation consisting of a two-parameter Winkler-Pasternak foundation augmented by a Kelvin-Voigt viscoelastic model with a nonlinear cubic stiffness. The distribution of temperature and material constitutive of the stiffeners are continuously changed through the thickness direction. The cylindrical shell has three layers consisting of metal, FGM, and ceramic. The interior layer of the cylindrical shell is rich in metal, while the exterior layer is rich in ceramic, and the FG material is located between two layers. The nonlinear vibration problem utilizing the smeared stiffeners technique, the von Kármán equations, and the Galerkin method has been solved. The multiple scales method is utilized to examine the nonlinear vibration behavior of SSMFG cylindrical shells. The considered resonant case is 1:3:9 internal resonance and subharmonic resonance of order 1/3. The influences of different material and geometrical parameters on the vibration behavior of SSMFG cylindrical shells are examined. The results show that the angles of stiffeners, temperature, and elastic foundation parameters have a strong effect on the vibration behaviors of the SSMFG cylindrical shells.

Keywords: multilayer FG cylindrical shells; internal resonances; spiral stiffeners; thermal environment; nonlinear viscoelastic foundation; subharmonic of order 1/3

1. Introduction

Functionally graded beams are structural elements consisting of two different materials. Due to their low weight and high rigidity, these elements are commonly used in several industries, such as construction, aerospace, transportation, aeronautics, and marine. Therefore, knowing their static characteristic is essential for scientists and engineers. The two constituent materials of conventional composite beams are attached, which increases the risk of delamination. Notably, the continuous evolution of mechanical characteristics from the bottom surface to the top one eliminates the interface between the layers, an area of stress concentration.

Additionally, the FG structures have two essential properties: resistance to mechanical loading through the metal face and thermal loading along the ceramic side. Consequently, these characteristics attract many researchers to study and analyze the mechanical response of these material structures under different solicitations.

During the space plane project in 1984, Japanese researchers developed FG materials to resist ultra-high temperatures. The FG structures have been tested under high-temperature gradients across the cross-sectional thickness. Nowadays, FG materials are alternative materials widely used in aerospace, energy sources, nuclear reactors, optical, biomechanical, civil, automotive, mechanical, chemical, and shipbuilding industries (Sayyad and Ghugal 2019).

FG beams are often subjected to coupled (mechanical, thermal, and moisture) loading in several engineering areas.

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http://www.techno-press.com/journals/sem&subpage=7
ISSN: 1225-4568 (Print), 1598-6217 (Online)

Journal of Nano- and Electronic Physics *Журнал нано- та електронної фізики*
Vol. **15** No 1, 01022(5pp) (2023) Том **15** № 1, 01022(5cc) (2023)

Effect of Idealization Models on Deflection of Functionally Graded Material (FGM) Plate

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(Received 10 January 2023; revised manuscript received 14 February 2023; published online 24 February 2023)

Functionally graded materials (FGM) are a class of composites, in which the properties of the material gradually change over one or more Cartesian directions, the combination of which results in an assembly with higher performance than components taken separately. This class of composite materials has gained considerable attention in the engineering community, especially in high-temperature applications such as nuclear reactors, aerospace, and power generation industries. The aim of the current work is to study the influence of homogenization (idealization) models and thermal loads on static deflection behavior of sandwich functionally graded plate. Several micromechanical models have been employed to obtain the effective material properties of the two-phase FGM plate. The FGM plate is subjected to linear and no linear thermal loads. The integral theory used contains only four variable functions as against five in the case of other HSDTs. The governing equation are derived and resolved via virtual work principle and Navier's model. The accuracy of the proposed analytical model is confirmed by comparing the results with those given by others model existing in the literature.

Keywords: Homogenization, Sandwich plate, Functionally graded plate, Deflection, Navier solution.

DOI: 10.21272/jnep.15(1).01022 PACS numbers: 77.84. – s, 77.84.Lf, 78.66.Sq

1. INTRODUCTION

Materials are continuously developed from iron, pure metals to composite materials which are in use today. Pure metals have very limited use, since actual application may require contrary property requirement which cannot provide by using single metal. As compared to pure metals, alloys can be stronger and more versatile. Bronze which is alloy of copper and tin was the first alloy that was developed in 4000 BC (Bronze age). Since then, different mixtures of metals and non-metals were tried to combine strengths of multiple materials as per functional requirement[1]. Functionally graded materials (FGM) are a class of composites in which the properties of the material gradually change over one or more cartesian directions [2]. FGMs have a wide range of applications in various sectors due to their flexibility in making a particular composite material according to the requirement. FGMs are used in aerospace structures, military applications, medical applications, photoelectronic devices, automotive parts, and sporting equipment. FGMs are advantageous over conventional structural materials and layered composites due to their continuous change in characteristic properties, thermal stability, good damping properties, and high toughness. Additionally, they are used as coating materials which reduce heat loss from engine exhaust system components and can be used in high and low temperature zones. FGMs are also used in forming tools and cutting tools, making them a useful material for many applications.

There has been a considerable research report on thermal stresses, fracture, thermo mechanical response, buckling, free vibration, etc., of FGM structural elements during the last two decades [3]. Due to the importance and wide technical applications of FGMs structures, they have been addressed by many researchers [4].

The aim of the using the micromechanical models is to accurately predict the effective multiphysics properties. and to quantify the effect of microstructure on the multiphysics behavior of materials by the application of continuum mechanics to a small-scale. Several micromechanical models of FGMs have been reviewed in [5-9]. To assess the effect of the micromechanical models on the structural responses of FG plates.

In this paper at first time the influence of the thermal load with linearity and nonlinearity variations is presented. Then, the effect of the micromechanical models (Voigt, Reuss, LRVE and Tamura) are employed to determine the effects on the Center deflection $\bar{w}$ of the sandwich functionally graded plate.

2. PROBLEM DEFINITION AND GOVERNING EQUATIONS

2.1 Materials Properties

The geometry of the domain problem is assumed to a rectangular plate with thickness "h", length "a", and width "b". The plate has three layers (two faces sheet and a core) (Fig. 1).

The FG-face sheets are made by two materials Titanium (as metal) and Zirconia (as ceramic). The Table 1 resumed the values of The Young modulus, thermal expansion coefficients α and poison ratioν of Ceramic and metal phases.

The volume fraction of the FG-faces sheet are assumed varies as following functions.

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JOURNAL OF NANO- AND ELECTRONIC PHYSICS *ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ*
Vol. **15** No 5, 05007(4pp) (2023) Том **15** № 5, 05007(4cc) (2023)

Effect of Broken Glass Particle on Stress Transfer of Nylon Matrix Composite

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(Received 25 July 2023; revised manuscript received 19 October 2023; published online 30 October 2023)

Some of the material demands in the advanced industries cannot be fulfilled by monolithic materials. Therefore, composite materials have been developed. The combination of desired properties of thermoplastics and glass particles (high strength and high modulus) is the aim of composites production Particles are becoming increasingly popular reinforcing elements in products made by injection molding. Particles reinforcement allows the polymer to be processed employing the same methods as those used for unreinforced polymers. The loads are not directly applied to the reinforcements, but they are applied to the matrix and some of the loads applied are transferred to the particles. The development of micromechanics equations for the particulate composites follows along the same lines as those for the short fiber reinforced composites. Particles are used to increase the strength or other properties of inexpensive materials during reinforcement with other matrix materials. The objective of this study is to analyse the particle breaking effect in composite made of nylon 66 (PA) matrix reinforced with glass particles, in which the particles diameters of 19.61, 26.15, 39.22 and 78.45 μm were used. A volume fraction of 20 % was assumed in each model.

Keywords: Broken particle, Nylon matrix, Composite, Stress transfer, Finite element.

DOI: 10.21272/jnep.15(5).05007 PACS numbers: 81.05.Qk, 81.07.Lk, 81.07.De

1. INTRODUCTION

The different types of composite materials are defined according to the nature of the reinforcements which can be of very different natures. The reinforcements are particles, short or continuous fibers [1]. The addition of stiff reinforcements in thermoplastics is an established practice in the polymer industry, introducing a stiff second phase, substantial improvements in stiffness, strength, creep performance, fracture toughness, can be obtained [2]. Fibers are often used as reinforcement, although this often results in anisotropic properties. This can cause problems and variations in component dimensions. The high costs and technical difficulties associated with the evolution of the manufacture of fiber reinforced composites sometimes limit their use in many applications [3]. Particulate fillers in the form of spheres can sometimes be a better choice when tight tolerances or isotropic properties are required [2].

A composite material is said to be particulate when its reinforcement is in the form of particles that do not have a preferred dimension (Fig.1). They are used to increase the properties of materials during the reinforcement of the matrix [4], they are used to improve characteristics such as the rigidity of the matrix, the resistance to abrasion or the resistance to temperature, to increase the modulus of the composite, decrease permeability and also decrease ductility. They are also often used to reduce the cost of the material [5]. The geometric arrangement of the constituents and the shapes of the particles only play a secondary role [6], generally, the particles are spherical, ellipsoidal, polyhedral or irregularly shaped, they are added to a liquid matrix which subsequently solidifies in a certain process.

Young's modulus is significantly improved by adding micro and nanoparticles to a polymer matrix because the hard particles have much higher stiffness values than the matrix [7]. The particles can be treated or untreated during reinforcement. Particle-reinforced materials are more attractive due to their cost-effectiveness, isotropic properties, and ability to be processed using technology similar to that used for monolithic materials [8]. The behavior of the macroscopically isotropic particle-reinforced two-phase composite is mainly determined by the behavior of the constituent materials, the volume fraction of the matrix and the inhomogeneities.

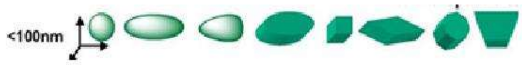

Fig. 1 – Different types of particles [5]

The purpose of this work is to analyze the broken particle effect of glass particle reinforced nylon 66 (PA) matrix composites considering the interaction between the matrix and particles interface. Particle reinforced composite is subjected to the longitudinal tensile loading.

2. FAILURE IN PARTICLE COMPOSITE

The incorporation of the particles in a matrix causes stress concentrations in the peripheries of the particle when the composite is subjected to loading [9]. Failure processes in particle-reinforced composites are related to the fundamental problem of a matrix crack interacting with second-phase particles [10]. The design against brittle fracture in composites is of critical importance [11]. Transmission electron microscopy has been used, but it is difficult to produce samples thin enough for the technique to be useful due to the presence of fragile reinforcements [12]. According to Vincent CARMONA [13], when the damage sequence is observed, the first visible mechanism is the rupture of large particles.

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Engineering Solid Mechanics12 (2024) 103-112

Contents lists available atGrowingScience

Engineering Solid Mechanics

homepage: www.GrowingScience.com/esm

Using finite element modeling to predict stress concentration factors in tubular T, Y and K joints

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A R T I C L E I N F O

Article history:
Received 17 August 2023
Accepted 6 November 2023
Available online
6 November 2023

Keywords:
Steel pipe
Welding
Tensile
Bending
Tubular junctions
Finite element

A B S T R A C T

Tubular offshore structures are commonly assembled using welded joints, creating areas of stress concentration and potential fatigue failure. This study focuses on tubular T, Y and K joints, a common offshore structural component. Finite element modeling is used to predict stress concentration factors (K_t) for various loading conditions on the T, Y and K joints. The goal is to calculate K_t values and compare them to existing theoretical solutions from literature. Additionally, the influence of different loading modes (tension, bending) on the K_t values is investigated. By using advanced modeling techniques, this work aims to provide new insight into the behavior of tubular T, Y and K joints connections under realistic offshore loading conditions. The results can help improve design standards and fatigue life predictions for these critical structural joints.

1. Introduction

Tubes are a crucial semi-finished product in steel production (V.A. M Steel Statistical Yearbook 2017). When analyzing structures under repeated loads, existing methods consider the impact of stress concentration on the development of fatigue phenomena (Jukić et al., 2021). However, in tubular assemblies, geometric discontinuities arise due to construction requirements, leading to stress concentrations, particularly near weld beads. These zones pose the risk of initiating and propagating fatigue cracks (Alaoui, 2015). Various researchers have explored stress intensity factors and crack analysis in different contexts (Zhen et al., 2016). Wang and Lambert (2003) employed the weight function method to calculate stress intensity factors for surface cracks in T-plate joints under arbitrary mode I loads. Mansouri et al. (2022) identified distinct microstructures in steel pipe welded joints. El Fakkoussi et al. (2019) utilized finite element methods to compute stress intensity factor K_t in mode I for a longitudinal semi-elliptic crack on the outer surface of a tube. Krešimir et al. (2021) studied thermo-mechanical simulation of welding processes, stress mapping, and stress intensity factor (K_t) calculation. Yao et al. (2023) explored the effects of various influencing factors on stress intensity factors along the crack front, considering crack closure and different conditions under internal pressure. Wang (2016) applied fracture mechanics principles to quantitatively analyze propagating cracks, solving the crack problem in T-shaped welded tees in waste heat boilers. Fustar et al. (2018) presented a review of common fatigue assessment methods used for welded steel joints. OH et al. (2012) estimated stress intensity factors for circumferential cracked pipes under welding residual stress fields.

The primary goal of this study is to calculate stress concentration factors Kt in T, Y and K shaped tubular joints and compare them with existing theoretical solutions in the literature. Furthermore, the research aims to investigate the influence of loading modes (tension, bending) on K_t values. By examining these factors, the study seeks to gain valuable insights into the behavior and structural integrity of tubular joints, particularly in the three shaped configurations, which can aid in optimizing their design and performance.

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ISSN 2291-8752 (Online) - ISSN 2291-8744 (Print)

doi: 10.5267/j.esm.2023.11.002

Journal of Computational Applied Mechanics 2024, 55 (1): 62-76

DOI: 10.22059/JCAMECH.2024.368866.909

RESEARCH PAPER

Investigating the Influence of Material Composition on Bending Analysis of Functionally Graded Beams Using a 2D Refined Theory

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Abstract

This study attempts to shed light on the analysis of the static behavior of simply supported FG type property gradient material beams according to an original refined 2D shear deformation theory. Young's modulus is considered to vary gradually and continuously according to a power-law distribution in terms of volume fractions of the constituent materials. The equilibrium equations are obtained by applying the principle of virtual work. The governing equilibrium equations obtained are thus solved by using the analytical model developed here and Navier's solution technique for the case of a simply supported sandwich beam. Moreover, Using the numerical results of the non-dimensional stresses and displacements are calculated and compared with those obtained by other theories. Two studies are presented, comparative and parametric, the objective of which is the first to show the accuracy and efficiency of the theory used and the second to analyze the mechanical behavior of the different types of beams under the effect of different parameters. Namely boundary conditions, the material index , the thickness ratio and the type of beam.

Keywords: Mechanical behavior; beams; Property Gradient Materials; Principle of virtual work; Navier's solution.

1. Introduction

Functionally graded materials (FGMs) are a class of advanced composite materials that have continuous gradation in composition and structure over volume, resulting in corresponding changes in the properties of the material [1, 2]. The concept offers the potential to optimize material response or functionality by tailoring the microstructure. FGMs eliminate the stress concentrations and singularities that often occur in laminated composites by providing smooth transitions in material properties [3].

Beams are a common structural element analysed in FGM research. A wide variety of analytical and numerical

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Journal of the Serbian Society for Computational Mechanics / Vol. 11 / No. 1, 2017 / pp 1-10
(DOI: 10.24874/jsscm.2017.11.01.01)

Numerical Study of the Behavior of a Zirconia Dental Prosthesis with Prior Defect

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Abstract

The biomechanics field continues with its progress and will not cease to grow due to ongoing research in this area to find better solutions to problems. It is in this context that this work aims to simulate the mechanical behavior of a dental prosthesis made from zirconia. The proposal of zirconia as a material for dental prosthesis is the main aim of this paper. Indeed, Zirconia as a bioceramic material presents many advantages, and especially good biocompatibility and high resistance of wear. On the other hand the disadvantage of this material is its fragility i.e. it has weak strength against cracking. So, in this paper we considered a dental prosthesis assumed to be implanted to an adult person. In order to study the crack initiation we considered a defect in this prosthesis. Using the conditions of blocking and loading by Abaqus simulating tool, we obtained the results revealing the possibility of using zirconia as a material for dental prosthesis.

Keywords: dental, zirconia, simulation, masticator

1. Introduction

Dental prostheses according to their types can be made of one of the following materials:

- Acrylic resins which are thermoplastic polymers.
- Ceramics, including zirconia, alumina and porcelain, are used in the manufacture of adjoining dental prostheses, crowns and bridges.
- Metals often used for posterior teeth include precious metals (gold, silver, etc.) and non-precious metals (nickel, chromium, cobalt, etc.) (Aiche et al. 1984, LeJoyeux 1978)

The zirconia is known by a set of properties making it a candidate material to be used in the biological human environment. Some of the important properties are cited as the following:

- Compressive strength close to 6000 MPa
- Purity up to 95.6%