International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 09 | Sep -2017 www.irjet.net p-ISSN: 2395-0072

Review on Functionally Graded Materials and various theories

Ashwinkumar A kokanee

PG student, Department of Civil Engineering, S.S.D.G.C.T.'s Sanjay Ghodawat Group of Institutions Atigre, Kolhapur– 416118, Maharashtra, India

---

Abstract - *Materials, energy and modern sciences are the three pillars of modern technology. New material developments and research are leading the invention of materials, as the cornerstone of 21st century high tech field. In recent years the materials science gained rapid developments. The reason is the increased interdisciplinary interactions as one hand and introduction of cross penetration of new theories, new methods and new experimental techniques on the other hand. Also, the urgent need for practical application of the material has put forwards new demands. The FGM is the one which can solve practical problems arising from production and application of new type of composite materials. These materials are used in aircraft because of their high performance and multifunctional role. In this paper study is performed on review of FGM composite materials.*

***Key Words*: FGM, Composite, Mori tanka.**

1. INTRODUCTION

Materials, energy & modern science are the three pillars of modern technology. Day by day lots of changes are occurred in this field. New technology will helps in production of smart materials all over the world. Hence various theories may put forward for the analysis use of such smart materials. FGM is the new sort of materials which can largely used in various civil and structural engineering applications such as aircrafts, nuclear reactors etc.

Functionally Graded Materials (FGMs) are the heterogeneous composite materials in which the material properties are gradually varied between two points in a predetermined manner. FGM can also be defined as a composite in which the material properties are gradually varied along a certain direction as a function of the position coordinates to achieve desired strength and stiffness. Thus, mitigating problems induced due to the sudden change of thermo-mechanical properties as in the case of laminated composites. Discontinuous changes such as a stepwise gradation of the material constituents can also be regarded as FGMs.

In this paper an attempt is made to study the various concepts of FGM composite materials.

2. Concept of FGM –

In the development of our society and culture materials have played an important role the scientific use of basic materials into various organic and inorganic compounds has made the way for developing the new materials.

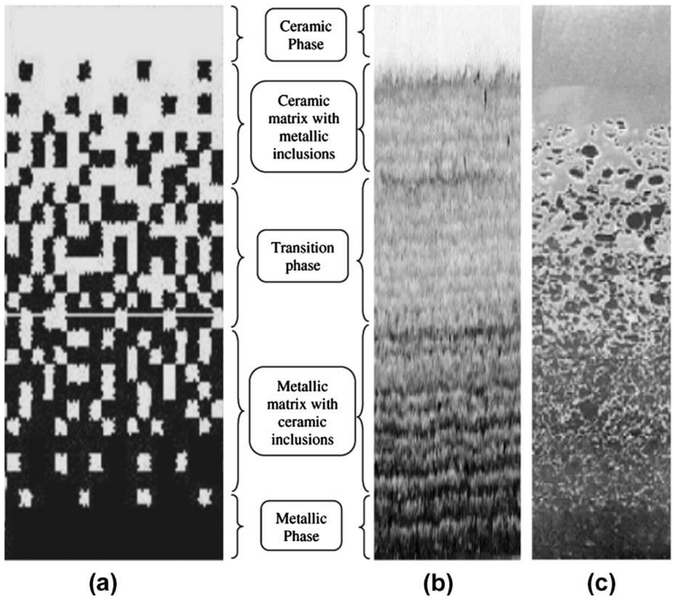

Figure 1 - Cross – Section of FGM materials (Jha et al. 2013)

Structure of development of modern materials explained in above figure1. Functionally Graded Materials (FGMs) are the advanced materials in the field of engineering made up of two or more composite materials with continuous smoothly varying compositions. FGM's have become more and more important in structural engineering due to their advantageous combination of the properties of two or more materials.

These advanced materials with engineered gradients of composition, structure and/or specific properties in the preferred direction/orientation are superior to homogeneous material composed of similar constituents. The mechanical properties such as Young's modulus of elasticity, Poisson's ratio, shear modulus of elasticity etc. will vary smoothly and continuously in preferred direction in Functionally Graded Materials.

These materials are gaining wide applications in various branches of engineering and technology with a view to make suitable use of potential properties of the available materials in the best possible way. FGMs for the present day modern technologies of special nuclear components, spacecraft structural members, and high temperature thermal barrier coatings, etc. These materials possess numerous advantages that make them appropriate in potential applications. It includes a potential reduction of in-plane and through-the thickness transverse stresses, improved thermal properties, high toughness, etc. FGMs consisting of metallic and ceramic components are well known to enhance the properties of thermal barrier systems, because cracking or delamination, which are often observed in conventional multi-layer systems are avoided due to the smooth transition between the properties of the components.

2.1 History of FGM

The best example of FGM is human skin which provides toughness, elastic qualities. The FGM materials often involved two isometric material constituents. This includes the alloys of magnesium, aluminum, ceramic titanium, steel, tungsten etc. FGMs have great potential in applications where the operating conditions are severe, including spacecraft heat shields, heat exchanger tubes, biomedical implants, flywheels, and plasma facings for fusion reactors, etc. Various combinations of the ordinarily incompatible functions can be implemented to create new materials for aerospace, chemical plants, nuclear energy reactors, etc. For example, a discrete layer of ceramic material is bonded to a metallic structure in a conventional thermal barrier coating for high temperature applications.

The abrupt transition in material properties across the interface between distinct materials can cause large inter-laminar stresses and lead to plastic deformation or cracking. These harmful effects can be eased by smooth spatial grading of the material constituents. In such cases, large concentrations of ceramic material are placed at corrosive, high temperature locations, while large concentrations of metal are placed at regions where mechanical properties need to be high.

The application of these advanced materials was first visualized during a space plane project in 1984 in National Aerospace Laboratory of Japan to avoid the stress peaks at interfaces in coated panels for the space shuttle.

The concept of FGMs has been successfully applied in thermal barrier coatings where requirements are aimed to improve thermal, oxidation and corrosion resistance. Two important research material systems in fabrication technology of FGMs are: Alumina ‘Al2O3’ and Zirconia ‘ZrO2’ exterior protective ceramic layers on Ni-superalloy ‘NiCrAlY’ based substrates.

2.2 Material Properties of FGM

The fabrication of FGM is made by mixing the two different materials often it will be the mixture of metal and ceramic. The material properties are depends upon the volume fraction .The analytical approaches, both finite element methods and micromechanical models are frequently used for FGM modeling. The most important subjects of FGM modeling are: elastic strain, elastic stress, plastic yielding and deformation, creep at elevated temperature, crack propagation, etc.

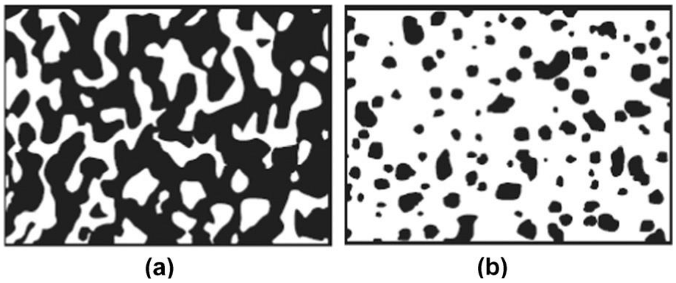

Figure 2 - FGM materials mixture microstructure (Jha et al. 2013)

3. Various analytical approaches

3.1 Mori tanka method

Such a method works well for composites with regions of the graded microstructure have a clearly defined continuous matrix This method assumes a small spherical particle embedded in a matrix. The matrix phase (denoted by the subscript 1), is assumed to be reinforced by spherical particles of a particulate phase (denoted by the subscript 2). K1, G1 and V1 represents the bulk modulus, the shear modulus and the volume fraction of the matrix phase respectively; whereas K2, G2 and V2 denote the corresponding material properties and the volume fraction of the particulate phase. It should be noticed that V1 + V2 = 1. The effective mass density at a point can be given by the rule of mixture (q = q1V1 + q2V2).

3.2 Composite sphere assemblage model

In this model, the effective properties of isotropic composite materials have been determined analytically, which is based on the simplifying assumption that the composite material is filled with a fractal assemblage of spheres embedded in a concentric spherical matrix of different diameters such that the spheres completely fill the volume of the composite.

3.3 Composite cylindrical assemblage model

This model is used for orthotropic composites and requires both the reinforcing fiber and matrix are isotropic, while the representative volume elements (RVEs) microstructure is transversely isotropic in material planes that are perpendicular to the fiber direction.

3.4 The simplified strength of materials method

This is a popular modeling method due to its ease of implementation and computational efficiency. This method assumes that the matrix phase is reinforced with, and ideally bonded to, a periodic array of square fibers. This method can also be used to estimate the orthotropic strengths of fiber reinforced composite laminate from the strength properties of the fiber and matrix constituents and the fiber volume fraction.

3.5 The method of cells

This is similar to Chamis's method of simplified strength of materials, but more computationally rigorous since it assumes a representative volume element that involves a larger portion of matrix material.

3.6 Micromechanical models

These models of representative volume elements may be constructed via FE simulations for either isotropic or orthotropic composite materials. Methods involving FE models attempt to accurately simulate the realistic microstructure of the RVE, and determine the thermo-mechanical response due to applied loads such that the effective material properties may be calculated for various volume fractions of constituent reinforcement. In this manner, various sets of curve fitted data may be collected for different material combinations. This is perhaps the most accurate method, since the microstructure under consideration is directly modeled via three-dimensional finite elements. Unfortunately, one drawback to this method is that multiple models must be constructed in order to determine material properties for various constituent material volume fractions; although this can be alleviated with proper computer software that can automate the process.

4. Research Studies on FGM

Sankar (1) presented an elasticity solution for a functionally graded beam subjected to transverse loads. A simple Euler–Bernoulli type beam theory is also developed on the basis of the assumption that plane sections remain plane and normal to the beam axis. Huang (12) developed studies on stress–strain modeling of adhesively bonded sandwich beams are briefly described in this study. Chakraborty et al. (7) developed new beam element to study the thermoelastic behavior of functionally graded beam structures. Zenkur (4) discussed two dimensional solutions for bending analysis of simply supported functionally graded ceramic metal sandwich plates.

Zenkur (5) presented the static response for a simply supported functionally graded rectangular plate subjected to a transverse uniform load. Bhangale et al. (6) studied buckling and vibration behavior of a functionally graded material (FGM) sandwich beam having constrained viscoelastic layer (VEL) is studied. Kadoli (9) studied displacement field based on higher order shear deformation theory is implemented to study the static behavior of functionally graded metal–ceramic (FGM) beams under ambient temperature. Sina (3) developed new beam theory different from the traditional first-order shear deformation beam theory is used to analyze free vibration of functionally graded beams. HenniAbdelaziz (11) performed a new displacement based high order shear deformation theory for static response of functionally graded sandwich plates. Jha et al. (8) performed an attempt to identify and highlight the topics that are most relevant to FGMs and structures and review representative journal publications that are related to those topics. Bui et al. (10) described transient responses and natural frequencies of sandwich beams with inhomogeneous functionally graded (FG) core. Mantari et al. (2) studied a static analysis of functionally graded (FG) single and sandwich beams by using a simple and efficient 4-unknown quasi-3D hybrid type theory, which includes both shear deformation and thickness stretching effects. Sobhy (15) described the vibration and buckling behavior of exponentially graded material (EGM) sandwich plate resting on elastic foundations under various boundary conditions. Swaminathan et al. (13) presented a comprehensive review of the various methods employed to study the static, dynamic and stability behavior of Functionally Graded Material (FGM) plates. Gupta and Talha (14) presented an extensive review related to the structural response of the functionally graded materials (FGMs) and structures have been presented.

5. Conclusion

A review of various investigations properties classifications applications is to be done in this study. An attempt is made to show the various theories used for analysis of FGM materials used in plates and beams. These theories are useful in various aspects of civil and structural engineering. This study is helpful to understand the nature of the functionally graded materials. FGM marks the emergence of modern material design into ideas for the development of new materials. Research, development and application of FGM materials have the current topic and have greater role in the field of aerospace engineering and structural engineering

REFERENCES

1. Sankar B.V. (2001) "An elasticity solution for functionally graded beams." Composites Science and Technology, Vol. 61, pp. 689–696.

2. Mantari J.L.(2015) "A simple and accurate generalized shear deformation theory for beams." Composite Structures, Vol.134, pp. 593–601.

3. Sina S.A, H.M. Navazi(2009) , H. Haddadpour "An analytical method for free vibration analysis of functionally graded beams." Materials and Design, Vol. 30, pp. 741–747.

4. Zenkour A.M. (2005) "A comprehensive analysis of functionally graded sandwich plates: Part 1—Deflection and stresses." International Journal of Solids and Structures, Vol.42, pp. 5224–5242.

5. Zenkour Ashraf M (2006)[c] "Generalized shear deformation theory for bending analysis of functionally graded plates." Applied Mathematical Modeling, Vol.30, pp. 67–84.

6. Bhangale Rajesh (2006) "Thermoelastic buckling and vibration behavior of a functionally graded sandwich beam with constrained viscoelastic core." Journal of Sound and Vibration, Vol. 295, pp. 294–316.

7. Chakraborty A (2003) "New beam finite element for the analysis of functionally graded materials." International Journal of Mechanical Sciences, Vol. 45, pp. 519–539.

8. Jha D.K, Tarun Kant,R.K. Singh (2013) "A critical review of recent research on functionally graded plates." Composite Structures. Vol.96, pp. 833–849.

9. Kadoli R et al. (2008) "Static analysis of functionally graded beams using higher order shear deformation theory." Applied Mathematical Modeling, Vol.32, pp. 2509–2525.

10. Bui T Q et al. (2013) "Dynamic analysis of sandwich beams with functionally graded core using a truly meshfree radial point interpolation method." Engineering Structures, Vol.47. pp. 90–104.

11. Hadj Henni ABDELAZIZ , Hassen Ait ATMANE , Ismail MECHAB, Lakhdar BOUMIA, Abdelouahed TOUNSI, Adda Bedia El ABBAS (2011) "Static Analysis of Functionally Graded Sandwich Plates Using an Efficient and Simple Refined Theory." Chinese Journal of Aeronautics, Vol. 24, pp. 434-448.

12. Huang Song-Jeng (2003) "An analytical method for calculating the stress and strain in adhesive layers in sandwich beams." Composite Structures, Vol.60, pp. 105–114.

13. Swaminathan K (2015) "Stress, vibration and buckling analyses of FGM plates—A state-of-the-art review." Composite Structures, Vol.120, pp. 10–31.

14. Gupta Ankit, Mohammad Talha (2015) "Recent development in modeling and analysis of functionally graded materials and structures." Progressin Aerospace Sciences, Vol.79,pp.1–14.

15. Sobhy Mohammed (2013) "Buckling and free vibration of exponentially graded sandwich plates resting on elastic foundations under various boundary conditions." Composite Structures, Vol. 99, pp.76–87.