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Editorial **Open Access**

Functionally Graded Material: A New Breed of Engineered Material

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Introduction and History of FGM

Materials have always been a crucial part of humans from the time the first man was created. As time progressed, so did the enhancement of technology and knowledge. Man started to engineer their own materials from existing raw materials. These engineered materials go back to 1000 BC in the form of composites of straw and mud. These composite improved over time and in the last four decades, the world was introduced with more sophisticated composites such as fiber reinforced plastics. However due to the limitations of delamination in such composites materials, another breed of composite material has given birth in the form of *Functionally Graded Material* (FGM). FGM is not new to us. Our nature is surrounded with FGMs. For example, the bone, human skin and the bamboo tree are all different forms of FGM. These breed of materials are the advanced materials in the family of engineering composites made of two or more constituent phases with continuous and smoothly varying composition [1]. FGMs are engineered based on different gradients of composition in the preferred material axis orientation. Due to this flexibility, FGMs are superior to homogeneous material composed of similar constituents.

Applications of FGM

So where do FGM fit in? FGMs have good potential as a substitute material where the operating conditions are severe. Examples includes coatings, heat exchanger tubes, flywheels, biomedical implants and turbine blades, no name a few. Usually coatings are just a layer sprayed over the substrate. Overtime due to severe operating conditions and abrupt transition of material properties from the coating to the substrate, high interlaminar stresses will exist, causing the spray to be worn or peeled off from the substrate. These sudden abrupt changes can be overcome by smooth spatial grading of the material constituents [2,3]. FGM is also findings its way into new applications such as nuclear fuel pellets, plasma wall of nuclear reactor, rocket space frame components, artificial bones, dentistry, artificial skins, building materials, sport goods, thermoelectric generators, optical fibers and lenses [4].

Effective Material Properties for FGM

In principle FGMs are fabricated by continuously fusing two discrete phases of materials together for an example, a distinct mixture of ceramic and metal. To estimate the effective material properties via shape and distribution of particles may be a challenging task. The effective properties such as elastic modulus, shear modulus, density, etc. can be evaluated or estimated only on the volume fraction distribution. Several models have been developed over the years to calculate the effective properties of macroscopically homogeneous graded materials. Some of these models are the self estimates models [5-7], Mori-Tanaka method [8,9], the simplified strength of material method [10,11], and the micromechanics model [12,13]. The micromechanics model is perhaps the most accurate method, since the microstructure under consideration is directly modeled via three-dimensional finite elements.

It is very important to assume the FGMs as heterogeneous material. To be able to understand the smooth changing of the material properties with respect to the spatial coordinates, the FGM has to undergo some homogenization schemes. The material properties are generally assumed to follow gradation through the thickness in a continuous manner. In the literature, the most commonly used analytical models are the exponential law and power law [14].

Research Studies and Future works on FGM

In the literature, there has been a lot of research work that has been done on the analysis of FGM; in particular FGM subjected to thermo elastic conditions, vibration and stability issues. Most of these works focus on 2D models. There is a need to develop 3D models to understand the out of plane response due to thermo-mechanical loadings. There is also a need to use higher order theories combined with non local stress analysis. In general, FGM holds a good potential in many applications. Research work should now slowly progress beyond the elastic limit, especially in the understanding of crack propagation due to fatigue. Modelling would not be sufficient here. It has to be supported with substantive experimental work.

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