World Journal of Mechanics, **2013, 3, 245-255**
http://dx.doi.org/10.4236/wjm.2013.35025 Published Online August 2013 (http://www.scirp.org/journal/wjm)

Characteristics of the Elastic Response of Isotropic Linear Micropolar Solids under Imposed Loads

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Received April 12, 2013; revised May 29, 2013; accepted June 24, 2013

ABSTRACT

This article proposes a simplified way to solve solid mechanic problems in micropolar elasticity using the solution found in the classic theory of elasticity as a starting point. In this study, an analysis of the linear isotropic micropolar elasticity is conducted based on the properties imposed on the micropolar medium by the constitutive and equilibrium equations. To ascertain how the micropolar medium responses deviate from Hooke's theory of elasticity, different loading conditions were classified. Three cases have been found so far: the rotational couple response, the quasi-classic equilibrium of momentum response and the general case. This study is the first in a series planned to explore the use of commercial packages of finite element in order to solve micropolar elasticity problems.

Keywords: Strength of Materials; Elasticity; Microcontinuum; Micropolar

1. Introduction

There are a number of elasticity theories which are based on the assumption that a solid is a continuous medium [1]. One such theory is the classic elasticity theory based on Hooke's law and is the one on which most of the commonly used materials in engineering are based. This theory assumes that each point on the continuum possesses three degrees of freedom or displacements in three orthogonal directions. Some special materials with no symmetry in their microstructure cannot be properly modelled using the classic theory, because they present additional mechanisms which oppose to deformation. That is the case in some cellular structures such as bones, wood and special materials like liquid crystal elastomers. In the case of human bones, several factors affect the mechanical response among which are age, gender and density. Because of these factors there is a wide range in the variation among the mechanical properties of this solid [2] and alternative elasticity theories should be used to model them properly. Microcontinuum theories are one such alternative.

These theories posit that each point of a continuous medium exhibits more than three degrees of freedom. On a prefatory note these theories consider that additional degrees of freedom have to be considered from the directors which are understood to be the orientations of the medium points. The microcontinuum theories can be classified as: 1) micropolar elasticity that assumes rigid medium points that can rotate; 2) microstretch elasticity that assumes breathing directors; and 3) micromorphic elasticity that assumes fully deformable directors [3].

The theory of micromorphic elasticity states that all the points in a solid have three displacements u_k. It also states that solids have nine other independent degrees-of-freedom that are accounted in a 3 × 3 matrix containing the so-called director's components x_{kK}. Considering the simplest case in microcontinuum elasticity, the micropolar elasticity theory there are only three additional degrees of freedom namely the microrotations of the directors ϕ_k.

To date, most of the microcontinuous studies have been based on the theory of micropolar elasticity, which has been applied to granular composites [4] or to cellular and porous materials [5]. Alternatively, the theories of microstretch and micromorphic elasticity have been applied to liquid crystal and liquid crystal elastomers [6,7]. The liquid crystal elastomers have attracted a great deal