Accepted Manuscript

Longitudinal elastic tension of two-layered plates from isotropic auxetics-nonauxetics and cubic crystals

Robert V. Goldstein, Valentin A. Gorodtsov, Dmitry S. Lisovenko

PII: S0997-7538(16)30261-3

DOI: 10.1016/j.euromechsol.2017.01.001

Reference: EJMSOL 3392

To appear in: *European Journal of Mechanics / A Solids*

Received Date: 27 September 2016

Revised Date: 14 December 2016

Accepted Date: 4 January 2017

Please cite this article as: Goldstein, R.V., Gorodtsov, V.A., Lisovenko, D.S., Longitudinal elastic tension of two-layered plates from isotropic auxetics-nonauxetics and cubic crystals, *European Journal of Mechanics / A Solids* (2017), doi: 10.1016/j.euromechsol.2017.01.001.

Longitudinal elastic tension of two-layered plates from isotropic auxetics-nonauxetics and cubic crystals

Robert V. Goldstein, Valentin A. Gorodtsov, Dmitry S. Lisovenko*

Institute for Problems in Mechanics, Russian Academy of Sciences, Prosp. Vernadskogo 101-1, 119526 Moscow, Russia

Abstract

Elastic longitudinal tension of thin two-layered plate composed of materials having positive and negative Poisson's ratios (auxetics and nonauxetics) is considered. Isotropic materials and crystals with cubic fourfold symmetry axis coinciding with the direction of tension are analyzed. The analytical dependences for effective Poisson's ratios of the plates on the ratio of layer thicknesses, Poisson's ratios and Young's moduli ratios of initial joined materials are derived. It was found that effective Poisson's ratio do not follow the rule of mixtures. Violation is particularly essential for the strong initial isotropic auxetics and incompressible isotropic nonauxetics. Derivation of general formulas for effective Poisson's ratios and effective Young's modulus of two-layered plates from cubic crystals is given. The derived formula for effective Young's modulus in the limit of initial isotropic materials coincides with formulas obtained previously in the literature. We show several examples of cubic crystals, auxetics-nonauxetics such that effective Poisson's ratios of two-layered plates may substantially exceed Poisson's ratios of the initial crystals. Effective Young's modulus may also exceed Young's moduli of both initial crystals.

Keywords: Elasticity, Isotropy, Cubic crystals, Auxetics, Poisson's ratio

1. Introduction

Composites of auxetics (materials with negative Poisson's ratio) and nonauxetics (materials with positive Poisson's ratio) recently attracted attention due to anomalous mechanical behavior and the possibility of using in applications [1].

Intensive study of auxetics has been initiated by the papers [2, 3], in which the metal and polymer foams with negative Poisson's ratios were obtained experimentally. Theoretical and numerical studies have shown that the most frequently anisotropic materials, changing the sign of Poisson's ratio at the change of orientation (partial auxetics) are encountered under normal conditions. Partial auxetics constitute a significant portion of crystals of different syngonies: cubic [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19], hexagonal and rhombohedral (trigonal) [20, 21, 22, 23], tetragonal [24, 25, 26], orthorhombic [27, 28], monoclinic [29]. Even more auxetics are identified among nano/microtubes formed from such crystals [18, 21, 22, 24, 26, 28].

Earlier studies of layered composites of alternating auxetics and nonauxetics were focused on isotropic materials. In most cases, the behavior of effective Young's modulus was analyzed [30, 31, 32, 33, 34, 35, 36, 37, 38]. In [1, 30, 31, 32] attention was paid to large deviations of the results for effective Young's modulus of two-layered plates with auxetics from ones predicted by direct and inverse rules of mixtures (Voigt and Reuss models). A detailed analysis of a large influence of positive Poisson's ratio on effective Young's modulus of two-layered plates made of isotropic non-auxetic materials was carried out in [39]. It was also shown that deviations from the predictions by the rules of mixtures take place. In [1, 33, 34, 35, 36, 37, 38] an influence of auxetics was evaluated for three-layered and multi-layered plates.

*Institute for Problems in Mechanics, Russian Academy of Sciences, Prosp. Vernadskogo 101-1, 119526 Moscow, Russia. E-mail: lisovenk@ipmnet.ru