Designing new auxetic structures based on known 2D systems

P.S. Farrugia[1], R. Gatt[1], L. Mizzi[1,2], J.N. Grima-Cornish[1], and J.N. Grima[1]

[1]Faculty of Science, University of Malta, Malta
[2]Department of Engineering Sciences and Methods, University of Modena and Reggio Emilia, Reggio Emilia, Italy

During the past 40 years, a large variety of mechanisms have been devised in order to create structures that are able to exhibit a negative Poisson's ratio [1-8]. However, most of the proposed designs are two dimensional, meaning that in the third dimension the structure is either ignored or still behaves in a conventional way. While this has created a wealth of structures that can find various applications, confining auxeticity to two dimensions restricts the ability of controlling the mechanical properties in the third dimension. This trend appears to have been changing in recent years, with an increasing number of structures showing negative Poisson's ratio in three dimensions being proposed [9-12]. In this context, this work aims at presenting some of the recent progress made in this direction. A variety of structures will be discussed showing how it is possible to use a known auxetic 2D system to build a 3D one.

The work will also present a case study of the deformation of the square grid and its generalisation for large strains and it will be shown that the structures can be designed to attain an incremental Poisson's ratio which is negative for relatively large strains.

References

1. K.W. Wojciechowski, Constant thermodynamic tension Monte Carlo studies of elastic properties of a two-dimensional system of hard cyclic hexamers, Molecular Physics 61, pp. 1247–1258 (1987).
2. K.W. Wojciechowski, Two-dimensional isotropic system with a negative Poisson ratio, Physics Letters A 137, pp. 60–64 (1989).
3. D. Prall, and R.S. Lakes, Properties of a chiral honeycomb with a Poisson's ratio of −1, International Journal of Mechanical Sciences 39, pp. 305–314 (1997).
4. A. Alderson, K.L. Alderson, D. Attard, K.E. Evans, R. Gatt, J.N. Grima, W. Miller, N. Ravirala, C.W. Smith, K. Zied, Elastic constants of 3-, 4- and 6-connected chiral and anti-chiral honeycombs subject to uniaxial in-plane loading, Composites Science and Technology 70, pp. 1042–1048 (2010).
5. L.J. Gibson and M.F. Ashby, Cellular solids: structure and properties, Cambridge University Press, Cambridge (1999).
6. I.G. Masters and K.E. Evans, Models for the elastic deformation of honeycombs, Composite Structures 35, pp. 403–422 (1996).
7. J.N. Grima and K.E. Evans, Auxetic behavior from rotating squares, Journal of Materials Science Letters 19, 1563–1565 (2000).
8. J.N. Grima, P.S. Farrugia, R. Gatt, D. Attard, On the auxetic properties of rotating rhombi and parallelograms: A preliminary investigation. Physica Status Solidi B 245(3), 521–529 (2008).
9. D. Attard and J.N. Grima, A three-dimensional rotating rigid units network exhibiting negative Poisson's ratios, Physica Status Solidi (B) 249, pp. 1330–1338 (2012).
10. C.S. Ha, M.E. Plesha, and R.S. Lakes, Chiral three-dimensional lattices with tunable Poisson's ratio, Smart Materials and Structures 25, 054005 (pp. 6). (2016)
11. M.-H. Fu, B.-B. Zheng, W.-H. Li, A novel chiral three-dimensional material with negative Poisson's ratio and the equivalent elastic parameters, Composite Structures 176, 442–448 (2017).
12. M. Shokri Rad, Z. Ahmad, A. Alias, Computational approach in formulating mechanical characteristics of 3D star honeycomb auxetic structure. Advances in Materials Science and Engineering 2015, Article ID 650769 (2015).