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MULTISCALE MODELING OF PERIODIC CHIRAL CELLULAR MATERIALS

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Auxetic materials, which are characterized by negative Poisson ratio and non-conventional mechanical response including hyper-stiffness and strength, are mainly designed as cellular systems having periodic structure. The auxeticity of the material is generally obtained by designing the microstructure in such way to promote a biaxial/triaxial overall extension/contraction.

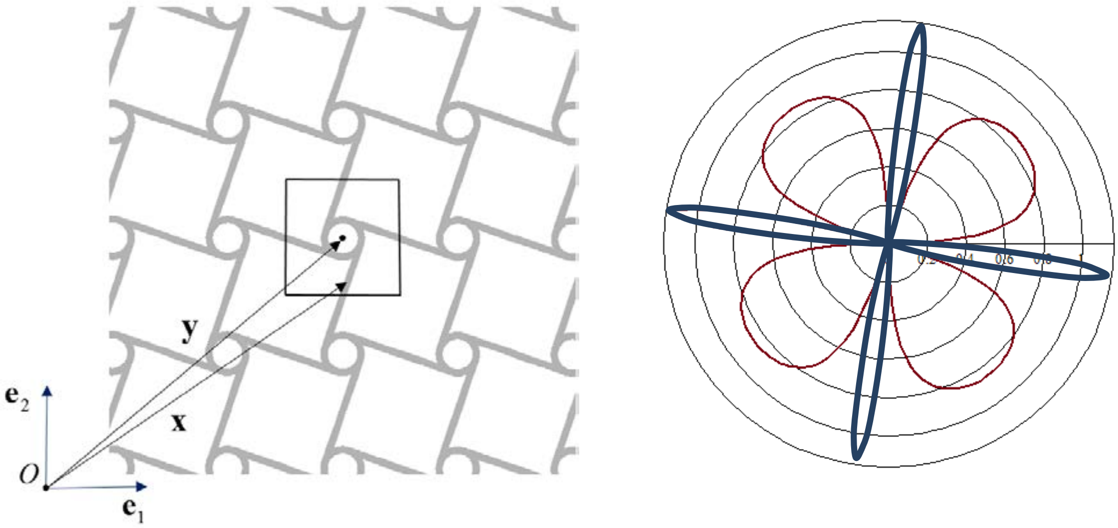
This effect is obtained through microstructural topologies which allow the material deployment through reentrant corners or winding/unwinding mechanisms, the last ones obtained through chiral or anti-chiral microstructures [1, 2]. In most cases, the material has a plane geometry and consists of an array of circular solid rings connected together with ligaments [3]. The formulation of the constitutive equations of materials having plane chiral microstructure is one of the main problems in the design of these materials, also in consideration of the fact that the manufacturing techniques may allow a considerable constructive flexibility [4].

The constitutive equations for both hexachiral and thetrachiral periodic cells are formulated in this paper and the corresponding elastic moduli are obtained through different methods of local and non-local homogenization. At first, the cellular material is modeled as a beam lattice with rigid circular rings and elastic beams with rigid ends to represent the ligaments and a micropolar equivalent continuum is obtained [2, 5, 6].

Afterwards, the problem of computational homogenization of chiral cells with thick ligaments and filled with a soft matrix is addressed through a second-gradient homogenization technique proposed by the Authors [7]. Here, generalized boundary conditions of periodicity (*GBC*) are introduced which guarantee the continuity of the micro-displacement field at the interface of adjacent cells.

For both the hexachiral and the tetrachiral cellular solids it is shown the dependence of the elastic moduli on the chirality index measured by the inclination of the legaments with respect to the center-lines of the cell array. Moreover, a comparison of the elastic moduli provided by the micro-polar and second gradient approaches is given with reference to the case of simmetric stresses, i.e. to the elastic moduli of the classical continuum. A further comparison concerns the different auxetic behavior of the two considered cellular arrays: the auxetic isotropy of the hexachiral model and the orthotropic auxeticity of the tethrachiral model.

Finally, the experimental results by Alderson et al. [3] are compared to the theoretical ones obtained by the homogenization techniques considered in this paper and those obtained by Dirrenberger et al. [8].



(a) (b)

Fig. 1 (a) Tetrachiral cellular solid; (b) Polar diagram of the overall Poisson ratio (red-positive; blue-negative).

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