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Stress channelling in polar materials

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Materials with extreme anisotropy display stress channelling and strain localization, effects that can be exploited in different technologies, for instance, in mechanical wave guiding, stress wave shielding, and invisibility cloaking. Theoretically, stress channelling was pioneered by Pipkin [1] and Spencer [2], who demonstrated that stress does not diffuse in materials with extreme orthotropic stiffness ratio, and was found to occur in masonry models by Bigoni and Noselli [3,4]. In the limit when the stiffness ratio between different material directions tends to zero, the equations governing equilibrium reach the elliptic boundary and the stress percolates through null-thickness deformation bands. In this situation, the material microstructure sets the percolation thickness and becomes a dominant factor.

The purpose of the present work is to analyze stress channelling and strain localization in extremely anisotropic elastic materials in the context of the constrained Cosserat theory (couple-stress theory). This theory introduces characteristic material lengths in order to describe the pertinent scale effects that emerge from the underlying microstructure and has proved to be very effective for modeling microstructured materials. The infinite body and half-space Green's functions are obtained analytically for orthotropic Cosserat materials, where the acoustic tensor is introduced ruling bulk plane-wave propagation. The Green's functions allow the investigation of the material behavior near the elliptic boundary, in the spirit of Bigoni and Capuani [5,6]. The overall goal is to obtain order of magnitude estimates of the thickness of the stress concentration zones in relation with the material microstructure. It is shown that the Cosserat effects influence significantly the localized deformation patterns and they are crucial in predicting the thickness of the stress concentration zones.

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