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# Waves in geomaterials with negative Cosserat shear modulus

Arcady Dyskin (1) and Elena Pasternak (2)

(1) University of Western Australia, School of Civil, Environment and Mining Engineering, Crawley, Australia (arcady_m@me.com), (2) University of Western Australia, Mechanical and Chemical Engineering, Crawley, Australia

Materials with negative moduli cannot exist on its own as they break the positive definiteness of the elastic energy making such materials unstable. They can however be statically stable as a part of an encompassing system that is stiff enough to stabilise the negative stiffness material. There indeed exist mechanisms that produce reversible descending branch giving rise to negative elastic stiffness (modulus). One such mechanism is rotation of non-spherical grains under shear stress in the presence of high compressive load. This mechanism creates an effect of negative Cosserat shear modulus that relates the non-symmetric part of the shear stress with the rotation.

While the negative shear modulus makes the potential energy non-positive, there still exists a range of values of this negative modulus at which the wave propagation is possible. All four types of travelling waves known in isotropic Cosserat continuum (p-wave, two shear waves and a twist wave) exist. Furthermore, while in the conventional isotropic Cosserat continuum the twist wave and one of the shear waves exist only at high frequencies, higher than a certain threshold frequency, the presence of formally negative Cosserat shear modulus removes this threshold and makes all four waves exist in all frequencies.

In general, negative values of the Cosserat shear modulus break isotropy making the corresponding Cosserat continuum orthotropic. This means that the properties of the travelling waves depend on the direction of travel. We investigate this dependence analyse the method to used the directional observations (measurements) of these waves can provide a method of detecting the presence of the negative modulus.