Geophysical Research Abstracts
Vol. 18, EGU2016-6283, 2016
EGU General Assembly 2016

Waves in geomaterials exhibiting negative stiffness behaviour

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Negative stiffness denotes the type of material behaviour when the force applied to the body decreases the body's deformation increases. Some geomaterials, for instance, rocks, demonstrate behaviour of this type at certain loads: during the compression tests the loading curves exhibit descending branch (post-peak softening). One of the possible mechanisms of the negative stiffness appearance in geomaterials is rotation of non-spherical grains. It is important to emphasize that in this case the descending branch may be reversible given that the testing machine is stiff enough (in general case it means an importance of boundary conditions). Existence of geomaterials with a negative modulus associated with rotations may have significant importance. In particular, important is understanding of the wave propagation in such materials.

We study the stability of geomaterials with negative stiffness inclusions and wave propagation in it using two approaches: Cosserat continuum and discrete mass-spring models. In both cases we consider the rotational degrees of freedom in addition to the conventional translational ones.

We show that despite non positiveness of the energy the materials with negative stiffness elements can be stable if certain conditions are met. In the case of Cosserat continuum the Cosserat shear modulus (the modulus relating the non-symmetrical part of shear stress and internal rotations) is allowed to assume negative values as long as its value does not exceed the value of the standard (positive) shear modulus. In the case of discrete mass-spring systems (with translational and rotational springs) the concentration of negative stiffness springs and the absolute values of negative spring stiffness are limited. The critical concentration when the system loses stability and the amplitude of the oscillations tends to infinity is equal to 1/2 and 3/5 for two- and three-dimensional cases respectively.