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Wave propagation is long chains of springs with negative stiffness elements

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We investigate dynamic stability, oscillations and wave propagation in a 1D chain of n (n»1) linear oscillators (masses and springs connected in series) with viscous damping when some of the springs' stiffnesses can assume negative values. We assume that the ends of the chain are fixed. Such chains can model interaction of rotating non-spherical grains or particles in the cases when some of them produce the effect of apparent negative stiffness (this depends upon the shape factor and the magnitude of compression in the vicinity of the grain).

It is shown that for such a system to be stable not more than one spring is allowed to have negative stiffness. Furthermore, the value of negative stiffness cannot exceed a certain critical value that depends upon the (positive) stiffness of other springs. At the critical value the system develops an eigenmode with vanishing frequency. In systems with small viscous damping vanishing of an eigenfrequency does not yet lead to instability. Further increase in the value of negative stiffness leads to the appearance of aperiodic eigenmodes with low and high damping. At the critical negative stiffness the low dissipative mode becomes non-dissipative, while for the high dissipative mode the damping coefficient becomes as twice as high as the damping coefficient of the system.

We consider systems of larger dimensions with chains that are non-interacting. We determine the concentration of the negative stiffness springs at which the system maintains its dynamic stability.