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SCHOCK ABSORBTION OPTIMIZATION OF COMPOSITE GRANULAR PROTECTORS

FERNANDO FRATERNALI[1] and CHIARA DARAIO[2]

[1]Department of Civil Engineering,
University of Salerno,
84084 Fisciano (SA), Italy
Email: f.fraternali@unisa.it

[2]Graduate Aeronautical Laboratories
and Department of Applied Physics,
California Institute of Technology,
Pasadena, CA 91125, USA
Email: daraio@caltech.edu

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ABSTRACT

It is well known that nonlinear system of interacting particles transport energy from coherent modes and macroscopic scales to internal, microscopic modes (*thermalization*), carrying localized traveling waves for generic nonlinear potentials V. Due to the zero-tensile strength and the nonlinear contact interaction law between the particles, granular systems present a strongly nonlinear interaction potential that can force traveling solitary waves to exhibit compact support (*compactons*) [1,2].

The thermalization effect can be used for fast decomposition of an external impulse into trains of solitons or compactons, energy trapping and shock disintegration, within optimally designed granular *protectors* or *containers*. Optimally randomized systems, involving e.g. scattering of particle sizes, masses and materials, show special dynamic features, such as: lack of uniform steady states of velocity profiles, high kinetic vs potential energy ratios, decay of wave amplitude, impulse disintegration and/or anomalous reflections through interfaces separating heavy (or hard) and light (or soft) particles, dependence of anomalous effects on the initial pre-compression.

The present study exploits the use of *Evolutionary Algorithms* for the optimal design of composite granular protectors through simultaneous material, geometry and topology optimization. Generations of candidate design solutions are evaluated in terms of a quantitative *fitness*, through numerical evaluation of the impulse absorption capability of the system.

Several optimization problems are examined, dealing with size, material and shape optimization of granular systems subject to dynamic impulses and shock-waves. The fitness is measured through the inverse of the maximum force F_{out} transmitted from the system to a given "wall", which simulates a large body in contact with the protector.

Comparisons with available experimental and numerical results show that the energy absorption features of the examined systems are dramatically improved by the optimal randomization process, which produces strong decomposition of the incident waves into solitary wave trains of decaying amplitude, and high thermalization of the system (cf. Figs 1 and 2).

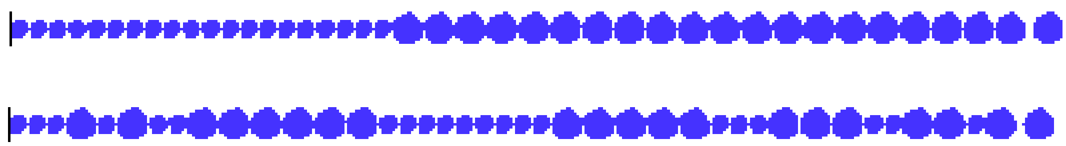

Fig. 1: Initial (*top*) and optimal (*bottom*) configurations of a two-radii granular chain subject to an impact with a striker (*rightmost particle*).

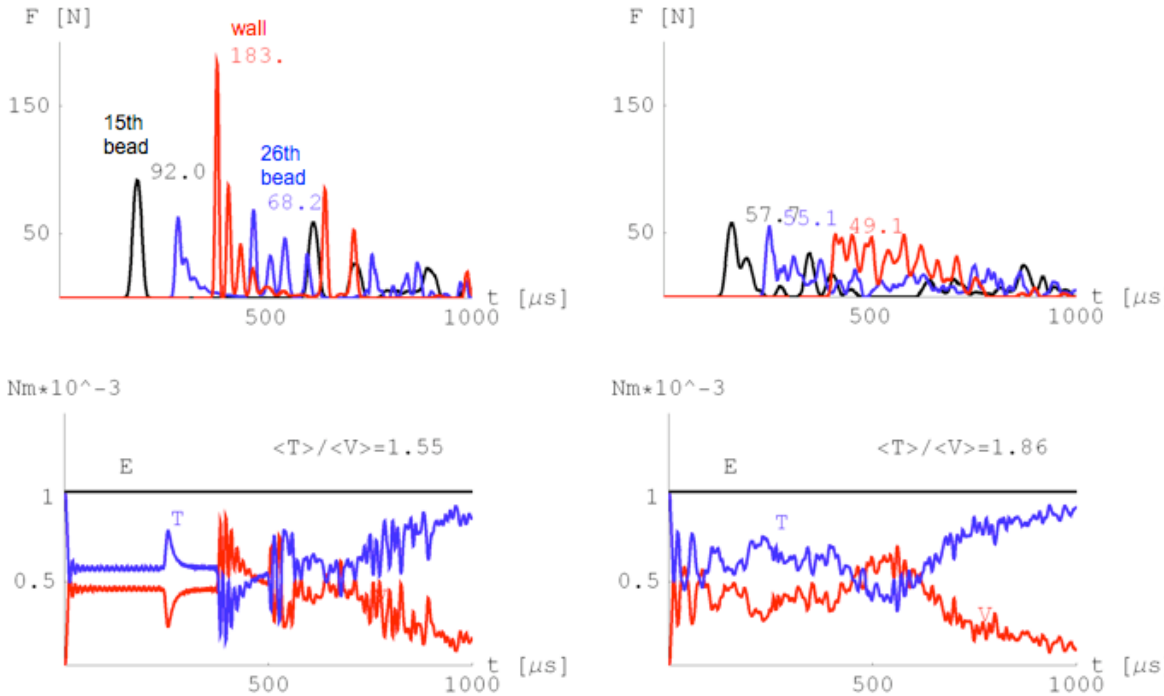

Fig. 2: Force and energy time-histories in the initial (*left*) and optimal (*right*) chains.

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