Design of Granular Chains to Reduce the Force Transmitted to a Fixed Barrier

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Abstract. We consider the problem of reducing the force transmitted through a strongly nonlinear granular medium when it is excited by an impulsive force at one end and restrained by a rigid barrier at the other. The medium consists of one or two parallel chains of spherical beads which interact only in compression, with contact forces described by a simple Hertzian model. By breaking the order of an otherwise homogeneous system, we scatter or confine energy within the chain(s) and shape the force pulse arriving at the end barrier.

Introduction

When a finite chain of similar, spherical beads is excited by an impulsive force at one end, a pulse propagates through the chain, eventually transferring energy to the final bead in the chain. If that bead is restrained by a stiff barrier, a reaction force is transmitted to this barrier as the pulse is reflected. The properties of the chain naturally influence the shape of the propagating pulse and thus the time history of the transmitted force. In this work we model the chain as spheres interacting in compression through Hertzian contact forces and seek to minimize the peak value of the transmitted force by adjusting the properties of beads in the chain; specifically, by introducing isolated lighter beads (light intruders) or sequences of several lighter beads (runs of light beads), we attempt to control the arrival of energy at the fixed end of the chain. The properties and number of these intruders and runs are designed to minimize the maximum value of the transmitted force.

We consider two systems, one consisting of a single chain and other of two chains in parallel. In the latter case, the coupling of the chains offers another parameter that may be adjusted in the design of the system. The more complex two-chain system is shown in Figure 1.

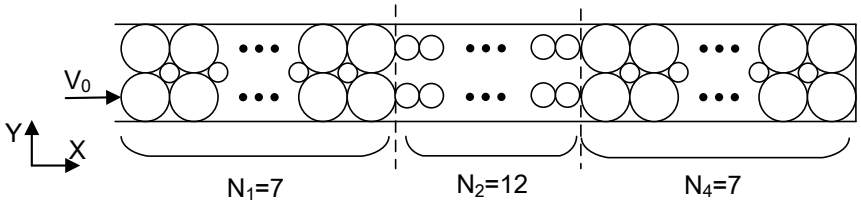

Figure 1: Geometry of the system of two parallel chains. The single-chain system is similar, but consists of only the lower (directly excited) chain.

The effects of the properties of the isolated intruders and the runs of light beads, and of their locations within the system, are examined first through numerical parameter studies. The results are described in terms of dominant physical phenomena, especially the local confinement of energy in the granular chains and the delay of its propagation, which are found to affect the force developed at the fixed end. On the basis of this understanding, optimal arrangements of beads are proposed to minimize the peak transmitted forces. These systems are studied in detail through numerical simulation, and the results are compared to experimental measurements of bead velocity made using laser vibrometry.

References

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