Angled Barbs and Granular Motion: A Biomimetic Approach to Particle Transport

Kaveeshan Thurairajah[1] , Joseph Owen[2], Michael Turco[1], Ash Lang[1], Nikhita Gone[1], Brian Kim[1], Disha Tandon[1], Kevin Deng[1], Zhao Pan[1]

1 Department of Mechanical & Mechatronics Engineering, University of Waterloo, Waterloo, Ontario, Canada

2 Department of Physics, University of Guelph, Guelph, Ontario, Canada

Nature finds a way – through ingenious solutions, survival is possible even in the harshest conditions. Within the deserts of Central Asia, a particular plant has evolved to burrow itself in the sandy soil. The seeds of this plant possess angled barbs which, when vibrated, propel the sand backwards and bury the seed for germination. With granular media being ubiquitous industrially – including foodstuffs, powder metallurgy, and additive manufacturing – harnessing this phenomenon has significant utility. We attempt to replicate and understand this phenomenon converting vibration into granular flow.

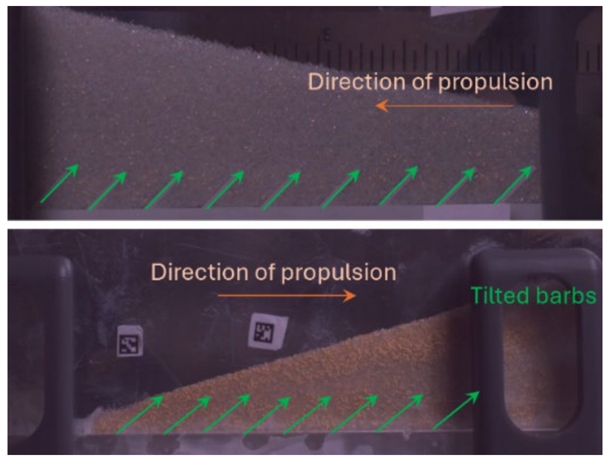

Figure 1 Experiments conducted on identical barbs showing flow to the left (above) and right (below) as frequency is varied.

We began by simulating our own version of the seed's fins to better understand the principles behind the conversion of vibration into granular flow. We constructed a Discrete Element Method (DEM) simulation using the Large Atomic/Molecular Massively Parallel Simulation (LAMMPS) software. Simulations demonstrate that the phenomenon is more complex than the base biological case, with flow that can be bidirectional, varying based on the physical structure of the barbs as well as the frequency of the vibration. Notably, we also predict that flow can be generated even in a microgravity system, indicating utility for applications in orbit.

The unique bidirectional flow has been shown experimentally as well. Experiments conducted with identical barbs can generate diametrically opposed flow at different frequencies, as seen in Fig 1. Interestingly this transition occurs twice with flow going right at low frequency, left at middle frequencies, and returning to right at high frequencies. We have constructed an apparatus to precisely vibrate test samples containing a single layer of granular particles and a barbed surface. Both replicating 2D simulations, and eliminating secondary convection induced by vibrating containers. High speed imaging is used to capture the motion of the particles, which is quantised using Particle Image Velocimetry (PIV). The entire test cell can be rotated to simulate a microgravity environment, allowing verification of 0g simulations. A phase diagram can be constructed showing how differing conditions result in flow in one direction or the other.

These computational and experimental results lay a foundation for the eventual development of a model of this system. This research is the first step in key applications within these critical fields.

Email address for correspondence: *kathurai@uwaterloo.ca*