Pulse-Elevator: Any-Directional Transport of Granular Materials

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A solid-state pulse-elevator can uplift and transport granular material in any direction via unidirectional vibration. This vibration can even be a hammering action, so augerless drills may be enabled.

What is a pulse-elevator? This is a modification of a Tesla valve, but designed for granular materials. When operated in an inverse manner – that is, with the oscillations being in the solid-state part and not in the working 'fluid', the granular material inside will (preferentially) flow in one direction only. Different solid-state device geometries can translate vertical oscillation into either vertical or horizontal transport.

The vertical behaviour can be modelled using 1D mechanics and propagated in FEA. This is shown in Fig.1 (with the FEA figure held in device-frame).

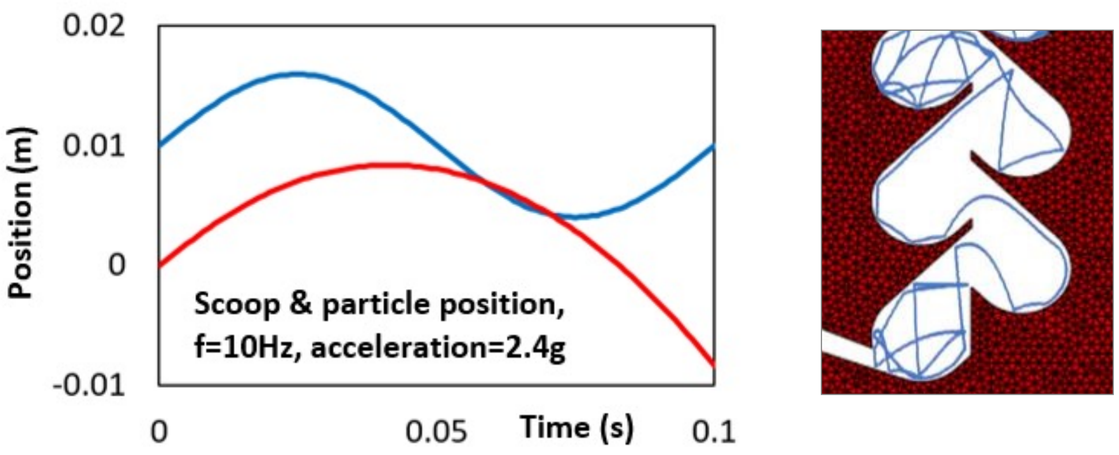

Fig. 1. Left, 10mm vibration (blue) just 'catches' the ballistic path of a particle (red), so 2.4g vibration is just enough to 'switch on' this device geometry. Right, paths are quite chaotic in practice.

The models, and our experiments in glass spheres, reveal dependencies with amplitude and frequency. Experiments (shown in Fig. 2) also suggest near-instant switching and highly linear performance.

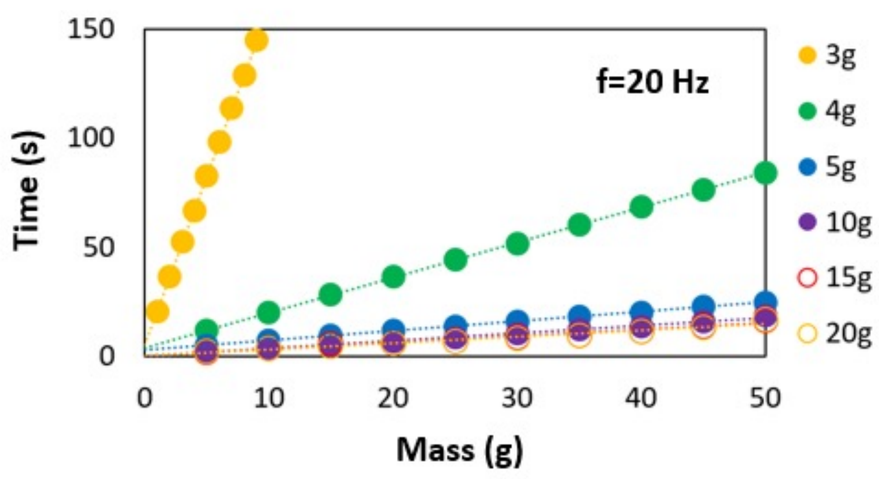

Fig. 2. The rate of uplift of glass microspheres increases with vibration amplitude, but reaches a plateau.

Beneficiation by supressing the uplift of less-dense particles with gas-blowing may be possible. Some wetness is tolerated, and sandy materials have proven to be tractable as well.

Applications in transport: Given the desired path, a solid-state geometry can be tailored to move materials from one end to the other. For example, the device in Fig. 3 can uplift, elevate, and move right and left to demonstrate the flexibility of the concept.

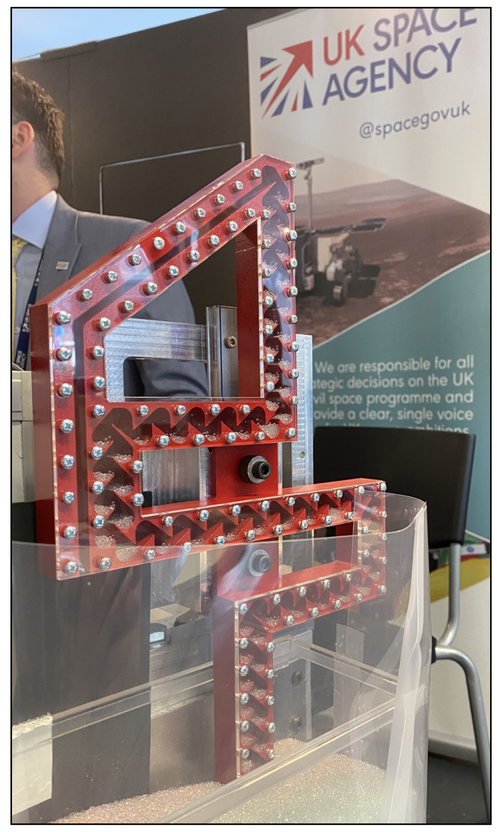

Fig. 3. A pulse-elevator can be tailored to suit a wide range of path requirements. This example was shown SRW in Luxembourg.

Applications in drilling: A pulse-elevator architecture inside a percussive drillbit can eliminate the need for augering. In experiments, a 30mm pulse-elevator (Fig. 4) was driven to 160mm in volcanic tuff, in 10 minutes.

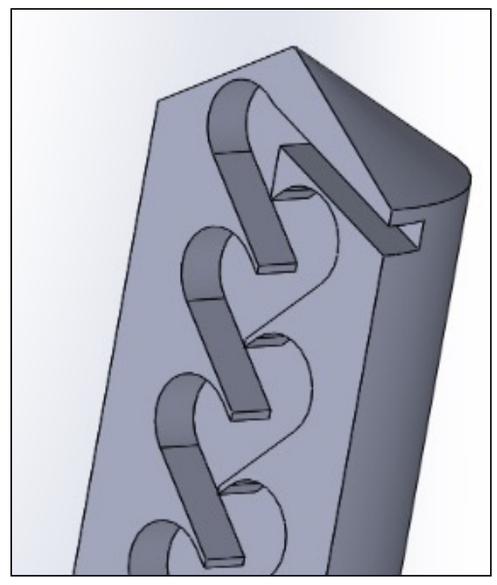

Fig. 4. A percussive pulse-elevator.

Operational performance: The behaviour of the system is best understood by observation (Fig. 5).

Fig. 5. A pulse-elevator in a range of materials and applications.

Key reference: Li, et al. Acta Astronautica 200, 2022, 33-41