THE PULSE-ELEVATOR: SIMPLE ANY-DIRECTIONAL TRANSPORT OF GRANULAR MATERIALS.

P. Harkness[1], X. Li[2], K. Worrall[3] and A. Scott-George[4]
[1]patrick.harkness@glasgow.ac.uk. Address: James Watt School of Engineering (JWSE), University of Glasgow, University Avenue, Glasgow, UK, G12 8QQ. [2]xuan.li@glasgow.ac.uk. Address: JWSE, as previous. [3]kevin.worrall@glasgow.ac.uk. JWSE, as previous. [4]andrew.scott-george@glasgow.ac.uk. JWSE, as previous.

Introduction: The uplift of granular materials is a major issue in drilling and comminution processes. Augering, (inclined) vibro-conveying, and bailing systems are commonly used, all of which have limiting issues related to their need to exploit particle friction, the range of inclination angles over which they can operate, the complexity of their mechanisms, and the forces or torques required.

In response to these drivers, the pulse-elevator was proposed [1]. This device, which is effectively a simplified Tesla Valve [2] for granular materials, can be incorporated into structural elements that may then be vibrated in a vertical direction, such that granular material inside the device moves (generally) upwards with each cycle of vibration. Fig. 1, adapted from [1], shows the simulated behaviour of some small spheres inside a pulse-elevator geometry: as the external (brown) architecture is vibrated vertically, the particles (black) move upwards overall.

This represents a simplification over concepts such as the dual-reciprocating drill, which require multiple relatively-moving parts [3], and it proves to be an effective technique in practice. Wall-friction is no longer required, as is the case in augering or vibro-conveyor systems, and in experiment the flow of material is extremely smooth. The material can also be uplifted from a hopper and does not fall back on stoppages, making metered delivery appear quite feasible. Most interestingly, the architecture can be created inside a drillbit and excited by a hammering action, enabling non-rotary borehole drilling and clearance.

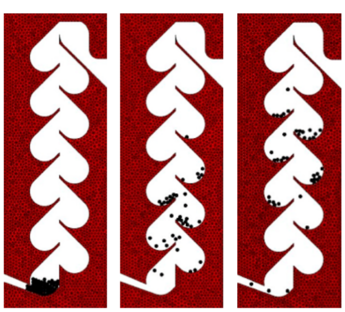

Fig. 1: A simulated pulse-elevator, adapted from [1]. The scoop diameter is 10mm, and the vertical excitation takes place at 10Hz with an acceleration of 5g. The time from first excitation is 0s, 0.3s, and 0.6s in the left, centre, and right frame.

The next step: However, it will be necessary to move granular materials along complex paths, both vertical and horizontal, in ISRU applications or inside drilling devices that need to move spoil materials topside. This is an issue for the pulse-elevator, as currently envisioned, because the direction of the excitation would need to be adjusted to match the desired path. Consequently discrete sections would be required for each directional segment of the journey, with discrete vibration engines, and materials handover between these sections would also be required.

The any-directional pulse-elevator is therefore proposed as an extension to the established concept. This architecture uses a different scoop geometry for its horizontal sections such that vertical excitation may drive material horizontally where required. In this way, a single custom-made solid-state device can move material in any direction when excited by a simple, low-amplitude uniaxial vibration.

The performance of the device: At the time of writing, the device has shown that it is functionally able to uplift 1mm glass microspheres from a hopper, move them up, to the right and to the left, and then eject them back into the hopper. This behaviour is seen when the device is excited over an 8mm amplitude at a frequency of around 6Hz.

Experiments are currently ongoing to characterize the performance of the new architecture, and clear IP issues that currently prevent communication of the scoop geometries used in the horizontal sections. These will be resolved before the conference date.

Summary: The pulse-elevator appears to be a novel concept that is best understood in video, and reviewers are invited to watch the system in operation here: https://www.youtube.com/shorts/tezBop_xufc

To summarise, the authors look forward to presenting a similar device, but extended such that both vertical and horizontal transport is possible, at the upcoming meeting in Colorado.

References:

[1] X. Li, et. al, (2022) *Acta Astronautical 200,* 33-41. [2] N. Tesla (1920). US Patent 1329559. [3] T. Gouache, et al, (2011) *Planetary and Space Science 59*, 1529-1541.