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DEM analysis of vibration propagation and damping in a silo with bulk solid

DEM analýza šíření a útlumu vibrací v zásobníku se sypkou hmotou

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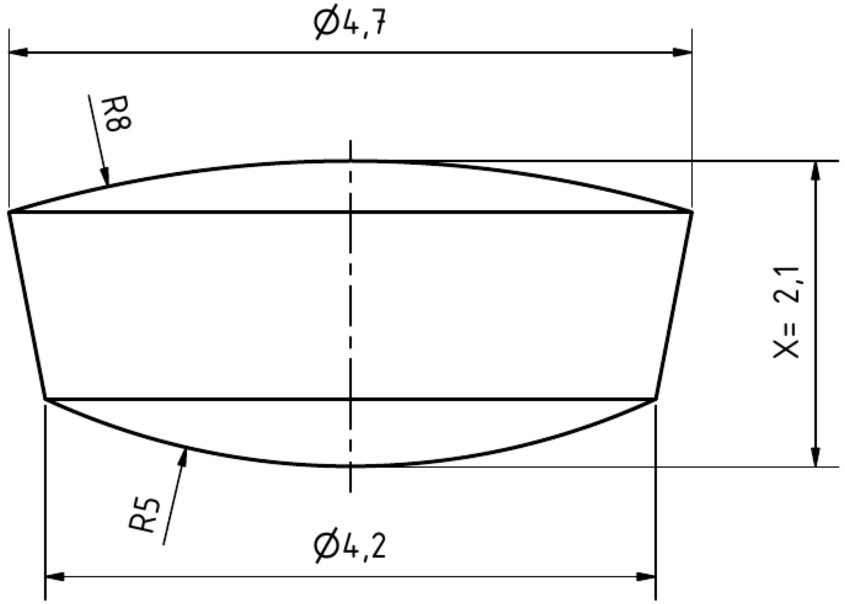
Motivation

- Dissertation: Loading of the storage system resulting from the vibration process of particulate materials
- DEM (discrete element method) requires a calibrated particle model as input
- The granulate is lens-shaped — particle shape governs packing, the contact network and dynamic response
- Goal: build and validate a shape-resolved DEM model of PE-HD LITEN TB38F

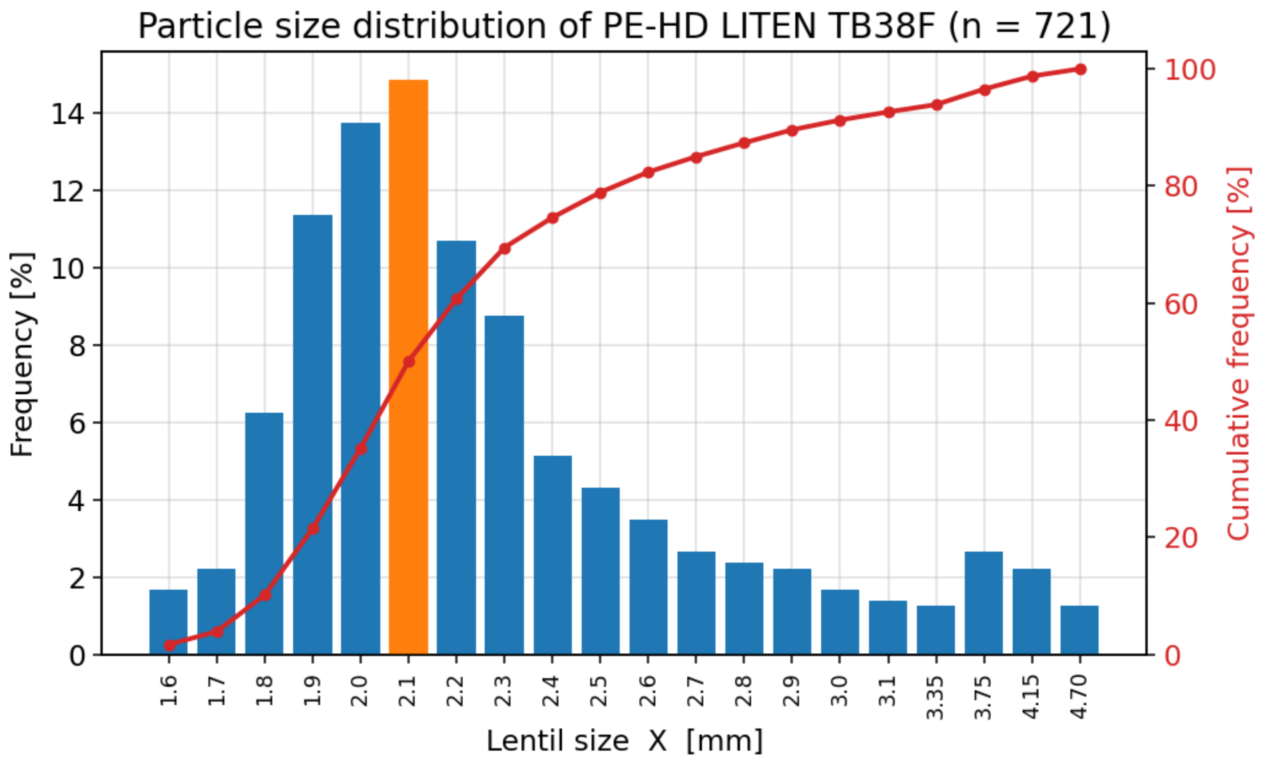
Bulk solid: PE-HD LITEN TB38F

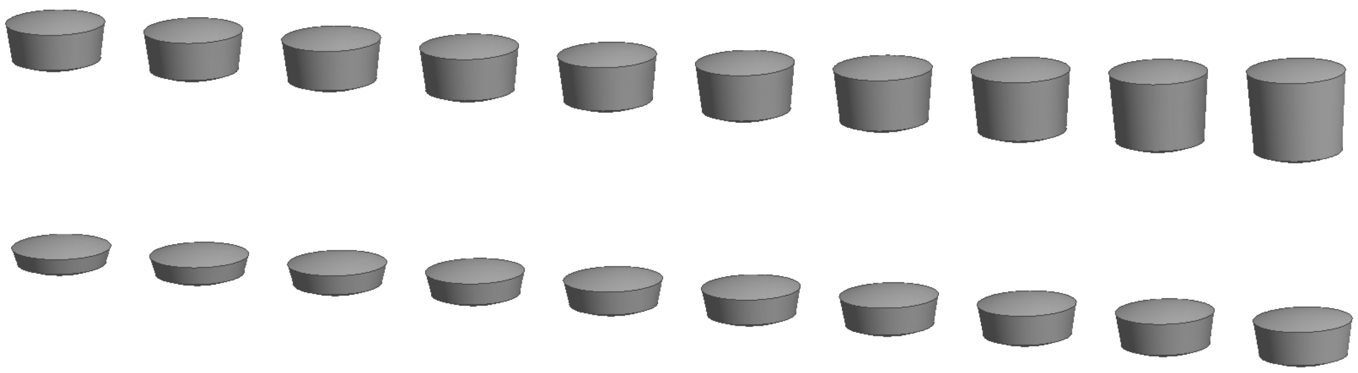
- Lens-shaped HDPE injection-moulding granulate
- Characteristic size X = 1.6–5.0 mm (caliper, 721 pcs)
- Solid density ρ = 952 kg·m^{-3}
- Strongly non-spherical → shape represented explicitly in DEM



Particle size distribution

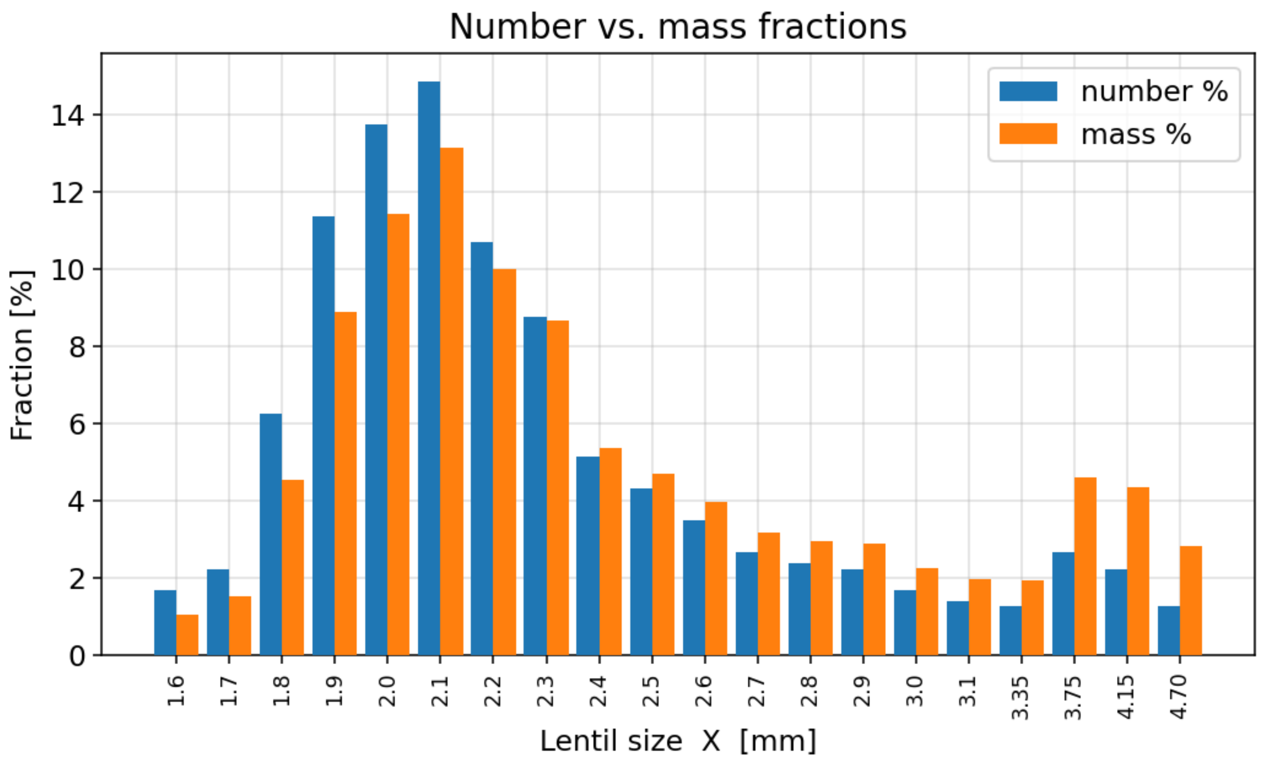
- 721 lentils measured, grouped into 20 size classes G01–G20
- Mode at 2.1 mm, right-skewed tail up to 5.0 mm
- EDEM works with mass %, not number %





From number to mass fractions

- Per-class volume from CAD model × ρ → mass of each size class
- Large lentils dominate by mass although few in number
- Mass-based distribution is fed to the EDEM particle factory



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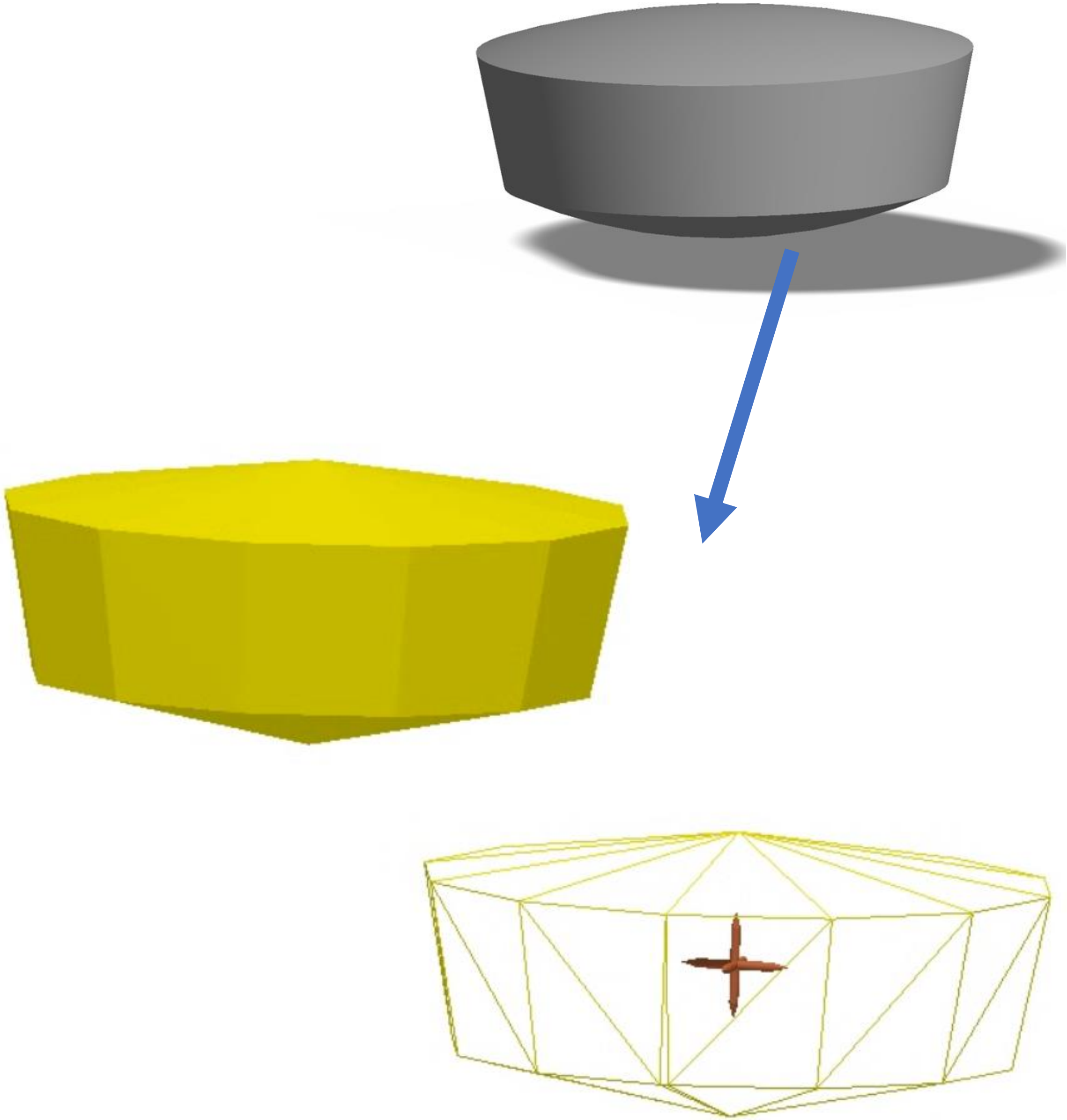
Particle shape model for DEM

- 20 lens models built in Autodesk Inventor (Revolve)
- Imported into EDEM as polyhedral particle
- Surface mesh optimised to keep shape at minimal element count

Import setting	Max Angle	Triangles / particle
Default	15°	≈ 110
Used	30°	≈ 48 (−56 %)



Material & contact parameters

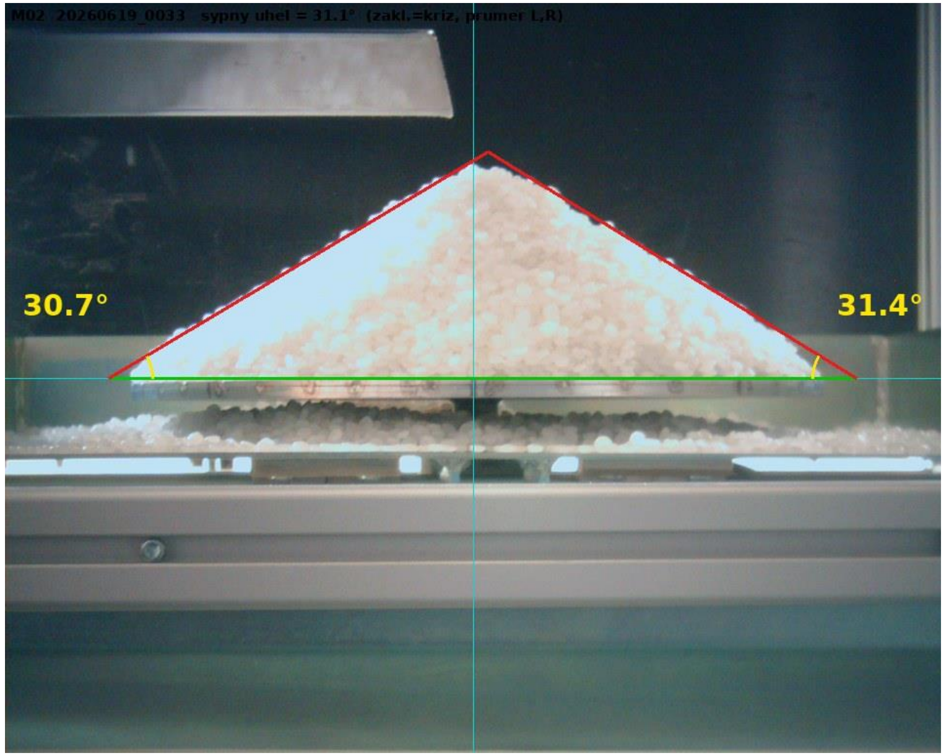
Determined by the same methodology presented by M. Dvořák, applied to our granulate:

Property	Particle (HDPE)	Wall (steel)
Density ρ [kg·m^{-3}]	952	7850
Young's modulus E	1.05 GPa	210 GPa
Poisson's ratio ν	0.40	0.30
Restitution ε	0.44 (p–p)	0.57 (p–w)
Static friction μs	0.28* (p–p)	0.12 (p–w)
Rolling friction μr	0.12 * (p–p)	0.12 * (p–w)

**calibration parameter*

Calibration & validation

- Rolling friction calibrated to the measured angle of repose (31.0° ± 0.4°)
- Bulk density (554 kg·m^{-3}) used as independent validation
- Restitution and shape kept fixed — avoids double counting



Angle of repose — annotated measurement

Application: vibration propagation & damping in the silo

- Validated model used to study how forced vibration propagates and is damped in the filled silo
- Particle shape changes interlocking and the contact network → affects wave transmission and damping
- DEM resolves bed rearrangement, compaction and energy dissipation
- ≈ 1.6 million particles

Simulation setup

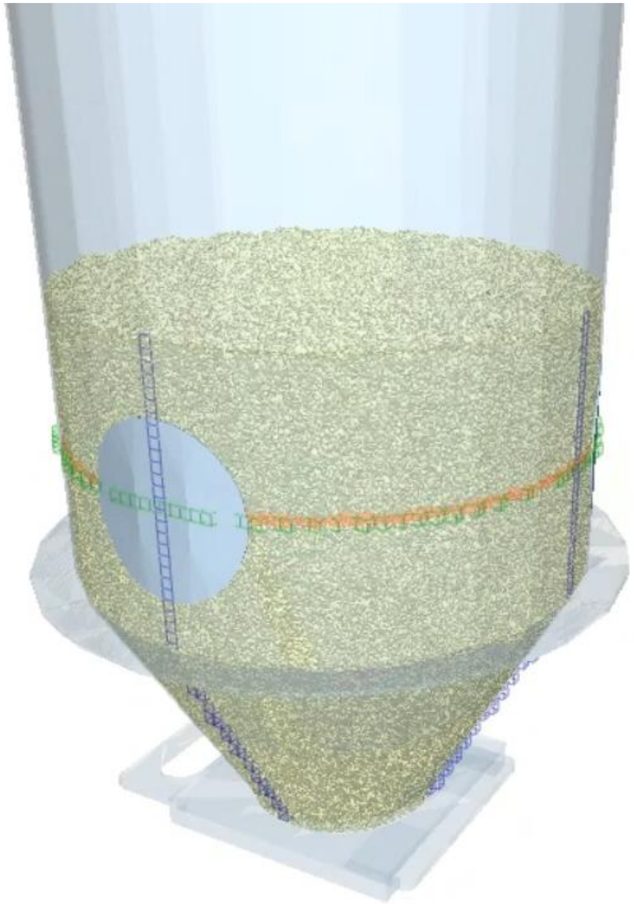
Solver & numerics

- EDEM — GPU CUDA solver (polyhedral particles)
- Hertz–Mindlin (no slip) contact model
- Explicit integration · Rayleigh time step 20 %
- Calibrated material & contact parameters

Geometry & excitation

- Silo Ø 475 mm, filled by volume packing (≈ 1.6 million particles)
- OT-8 turbine pneumatic vibrator: 2 bar → 566 Hz
- Wall-mounted; 1 / 2 / 3 sources spaced 120° apart
- Velocity field sampled on 3 orthogonal planes (9.5 mm cells)

Monitoring planes

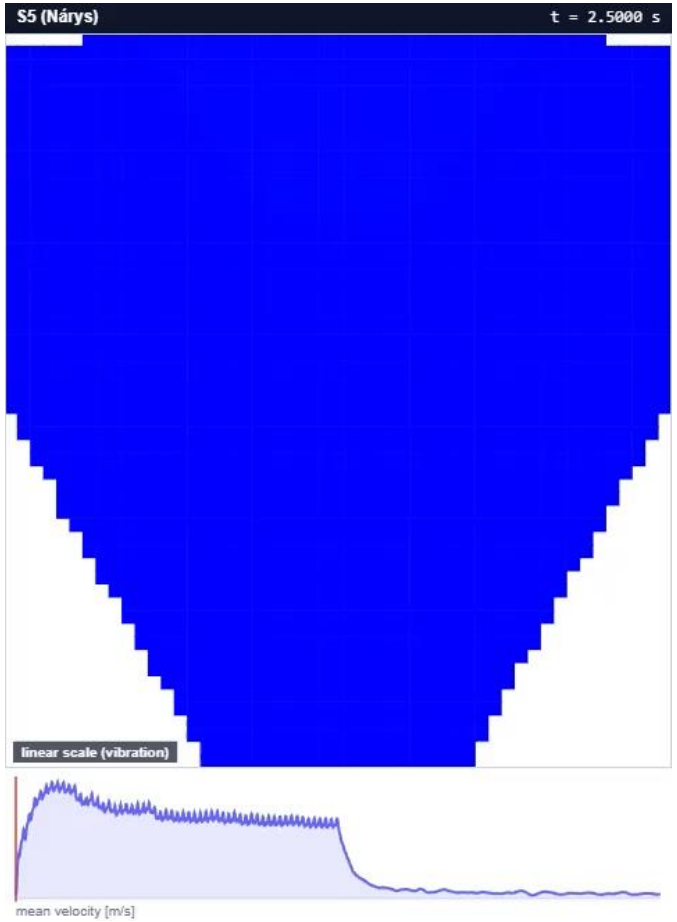


- The material volume in the silo is divided by three planes into top, front and side sections.
- Each plane is built from cube cells 9.5 mm on a side; for the 475 mm silo diameter that gives 50 cells across.
- Each cell records the mean velocity of all particles whose centroid lies inside it.
- These velocities are rendered in software built specifically for this purpose.

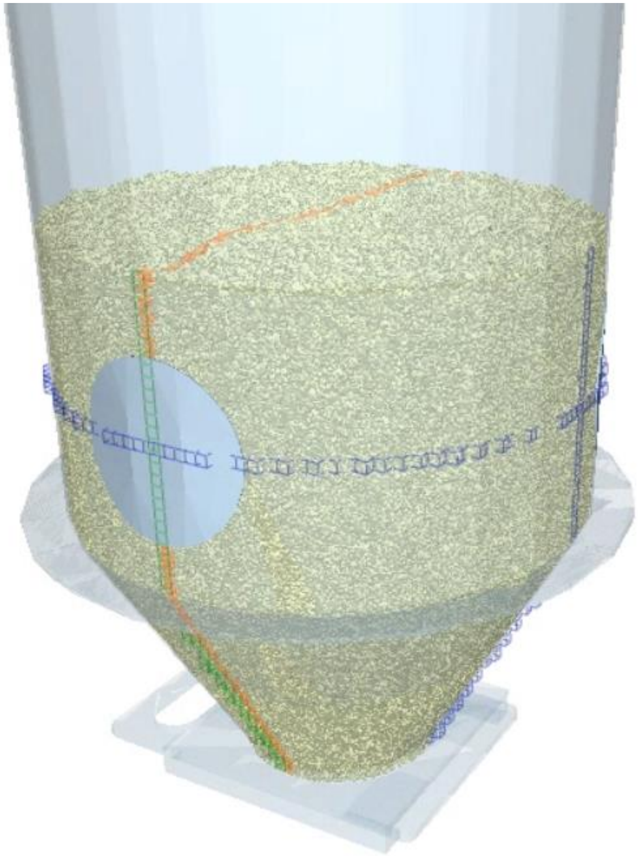
Custom analysis tool

The software reads the three DEM section exports (velocity field per cell) and exports figures and the wave-propagation videos.

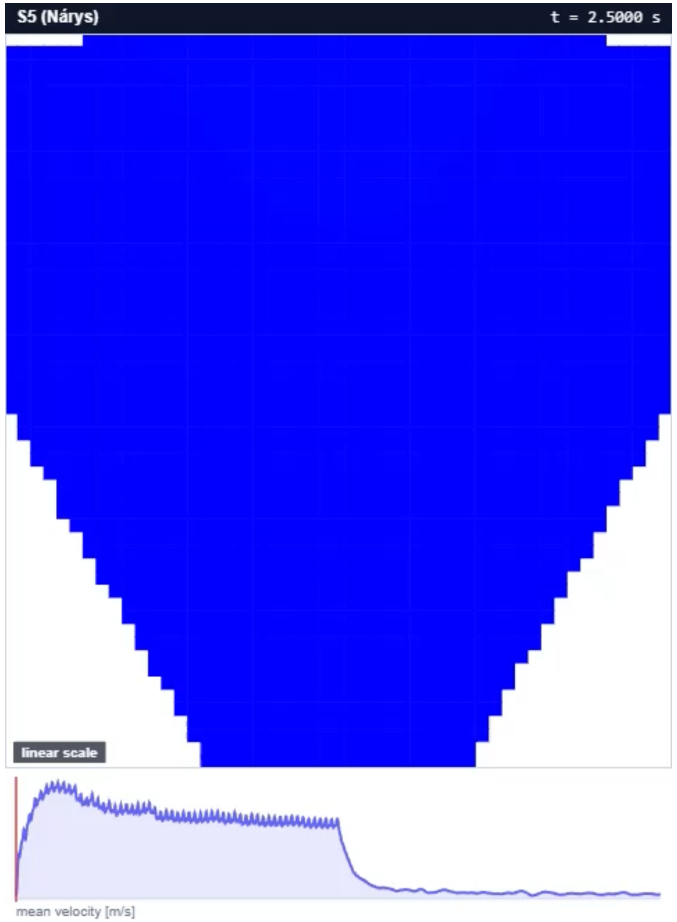
1 source LIN-LOG



Side view

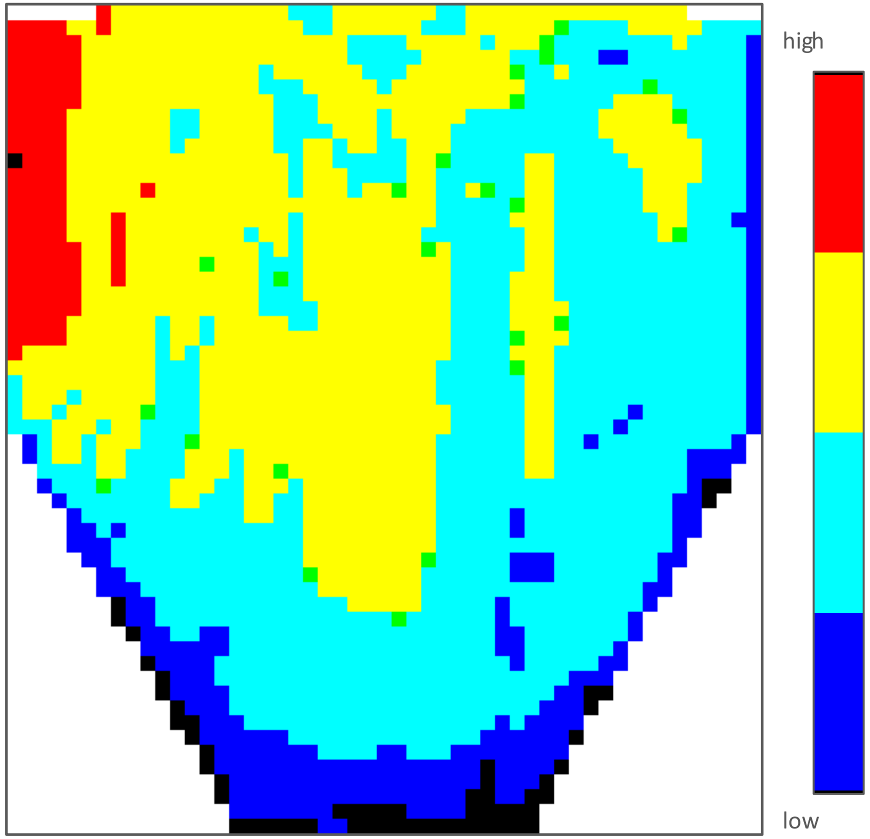


1 source LIN-LIN



Playback slowed 250× · clip shows 0.1 s of vibration + 0.1 s of decay · after the vibration ends a logarithmic scale reveals even trace velocities.

Vibration response: propagation pattern



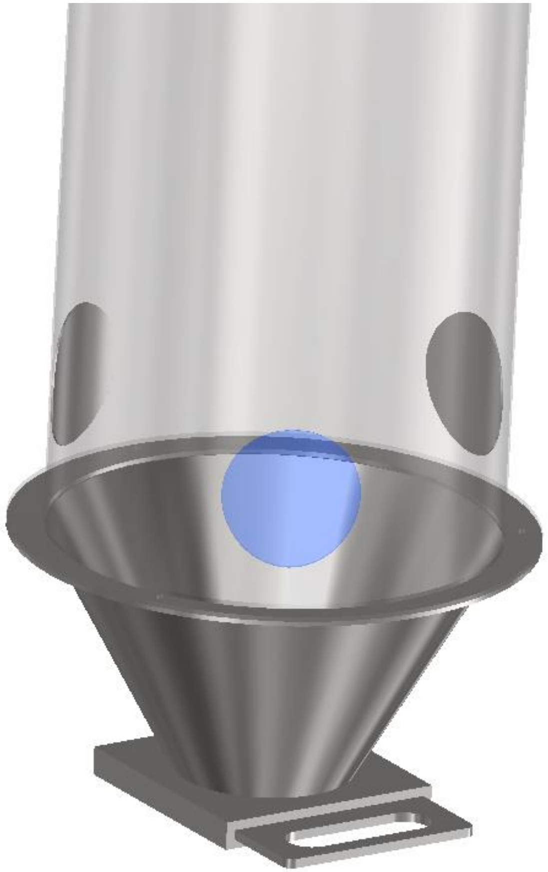
Vertical section — vibration enters at the wall source (red), penetrating the bulk and damping with depth and toward the surface.

Key observations

- Forced vibration (566 Hz) is injected at three wall vibrators, 120° apart.
- The active zone stays localized around the sources — amplitude drops steeply into the bulk.
- The far field and free surface fall to the log-scale floor, showing pronounced damping across the cross-section.

Effect of vibrator count

1 source



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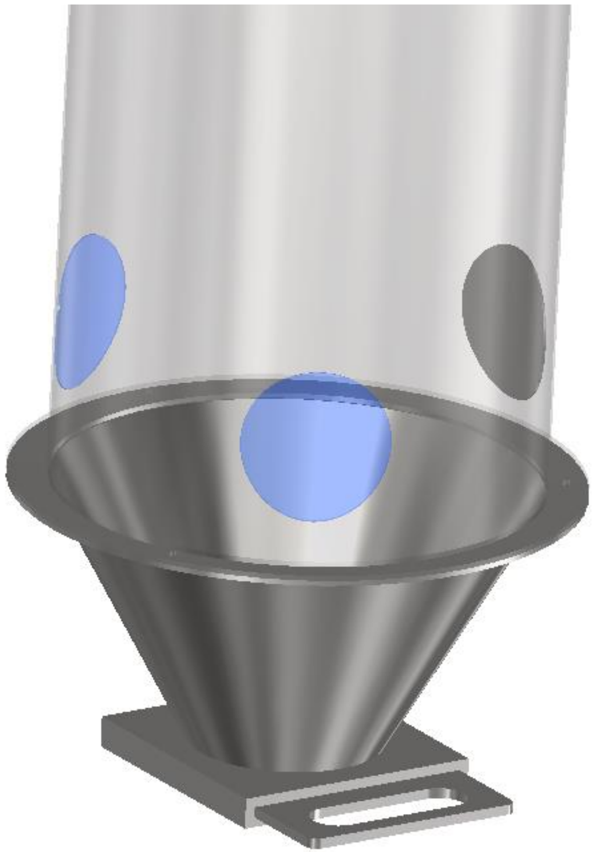

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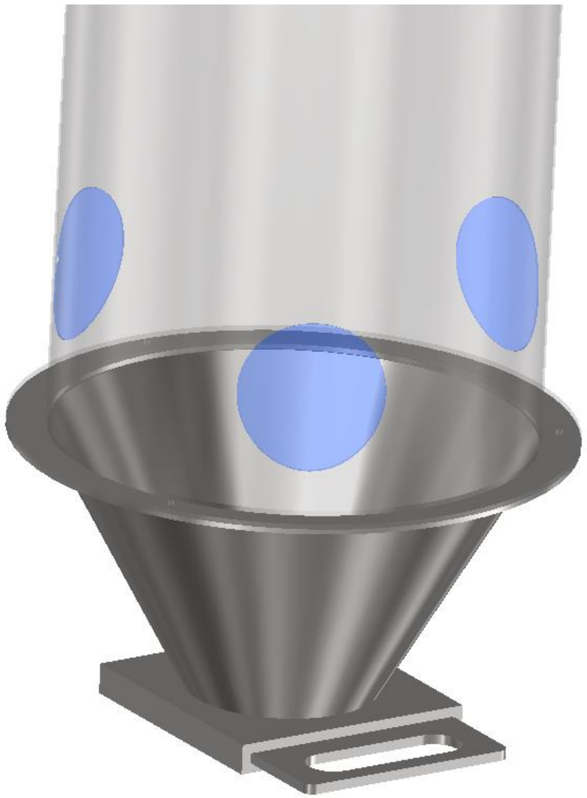

Effect of vibrator count

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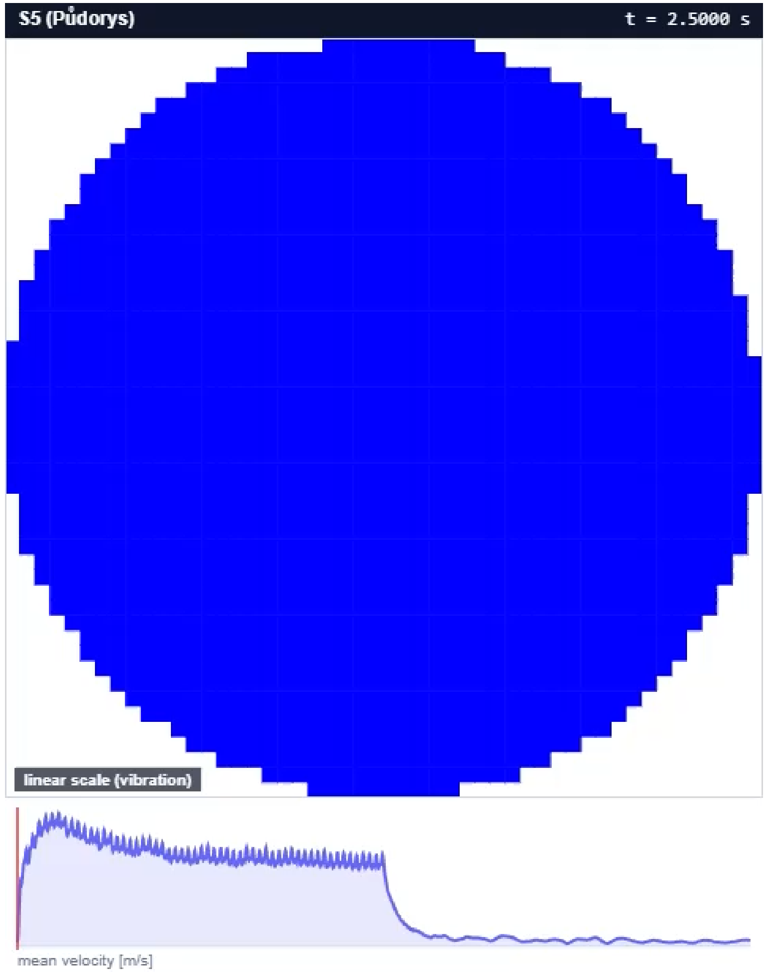

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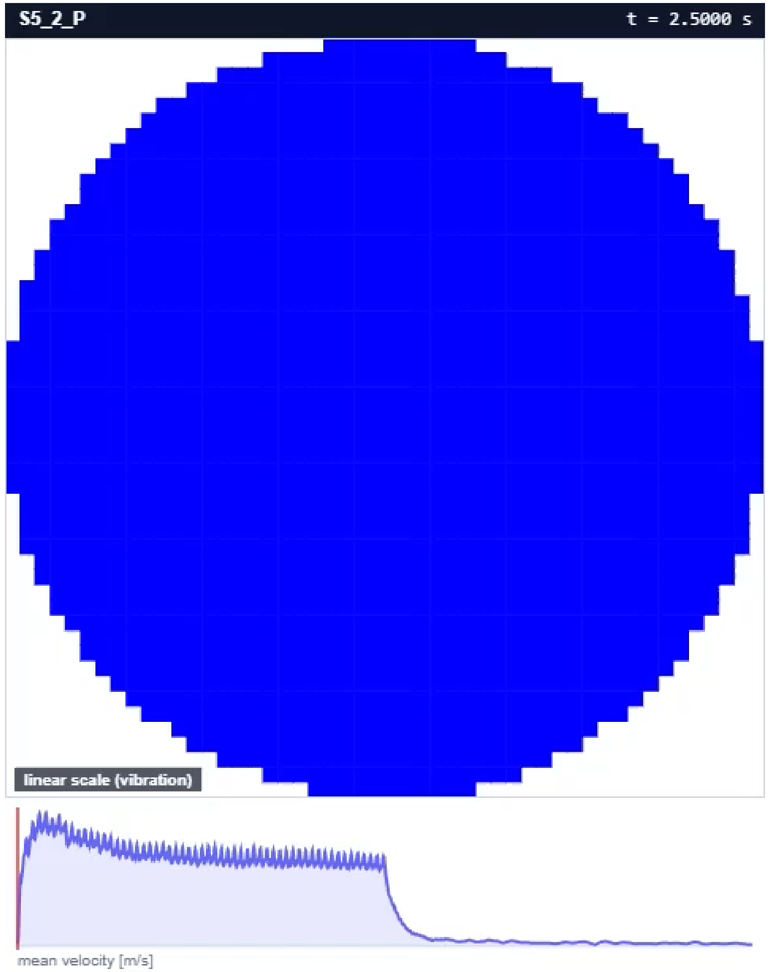

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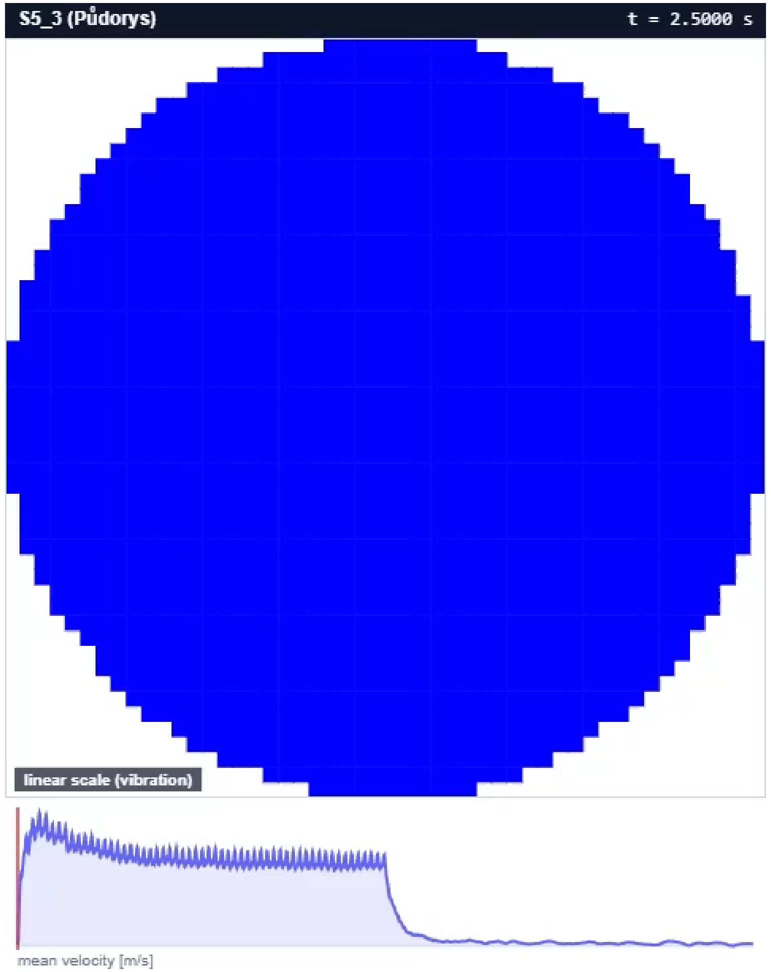

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Horizontal section at peak localization · colour = |v|, log scale (each panel normalized to its own peak)

Conclusion

- A shape-resolved DEM model of a lens-shaped HDPE granulate was built and validated
- Calibrated on the angle of repose, validated on bulk density
- First DEM results show the vibration localized near the sources and strongly damped; the next step is validation against accelerometer measurements on the physical silo

Thank you for your attention

Ing. Karel Břemek · Ing. Martin Dvořák · Advanced Engineering TechDay 2026