

XXIX International Mineral Processing Congress

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An investigation of particle shape effects on load movement in tumbling mills by discrete element method (DEM)

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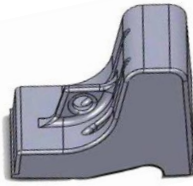


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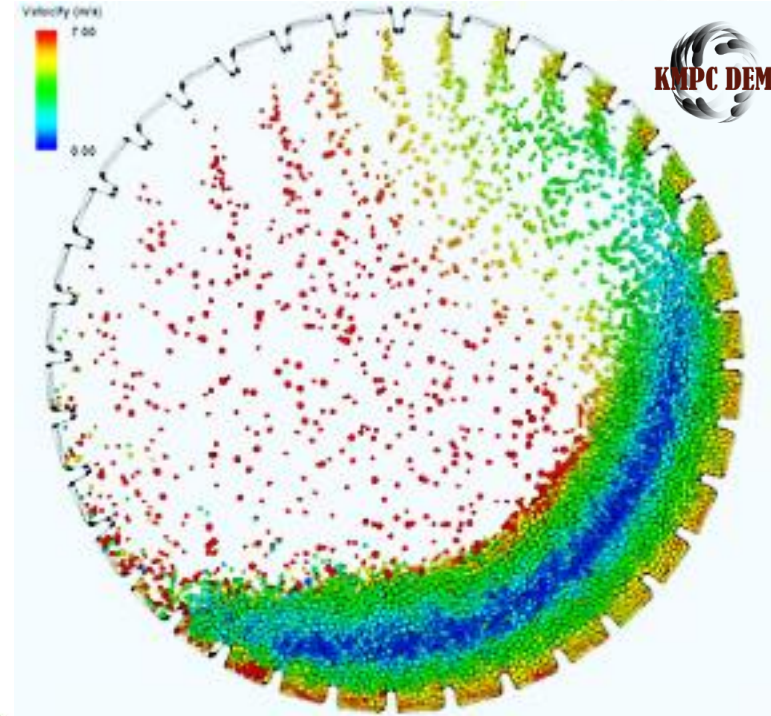
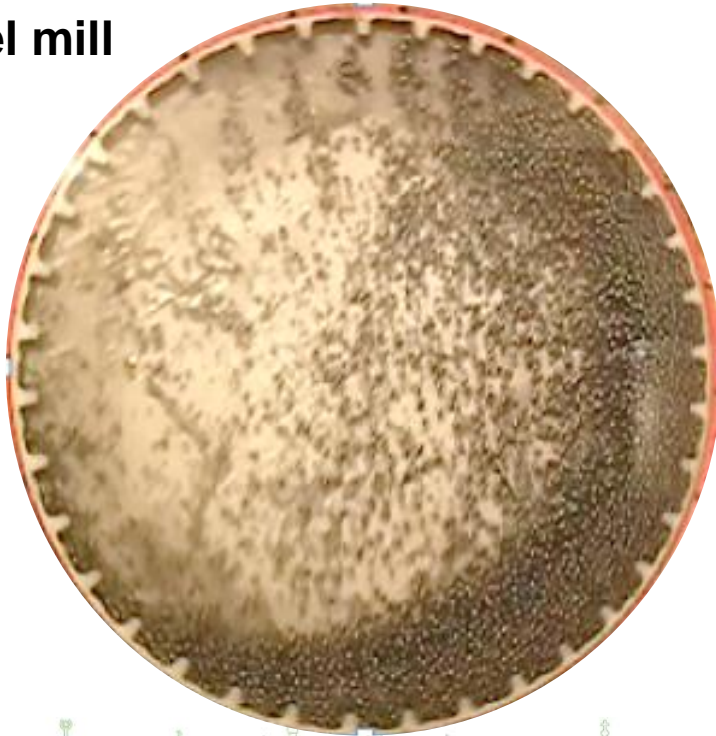
MOSCOW 2018

Charge trajectory

(Gol-E-Gohar iron ore SAG mill; original liner)



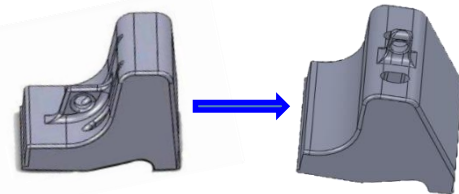
Model mill



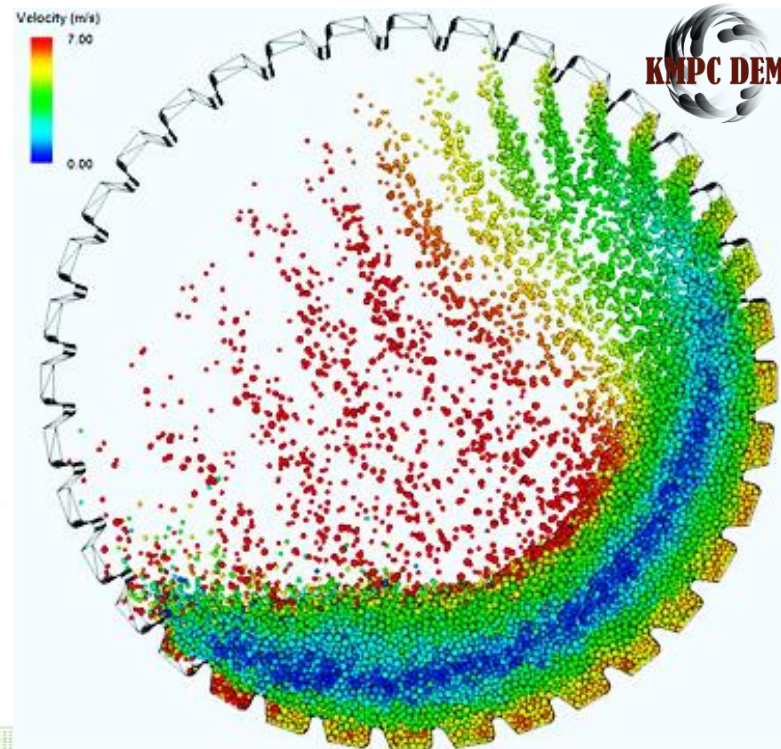
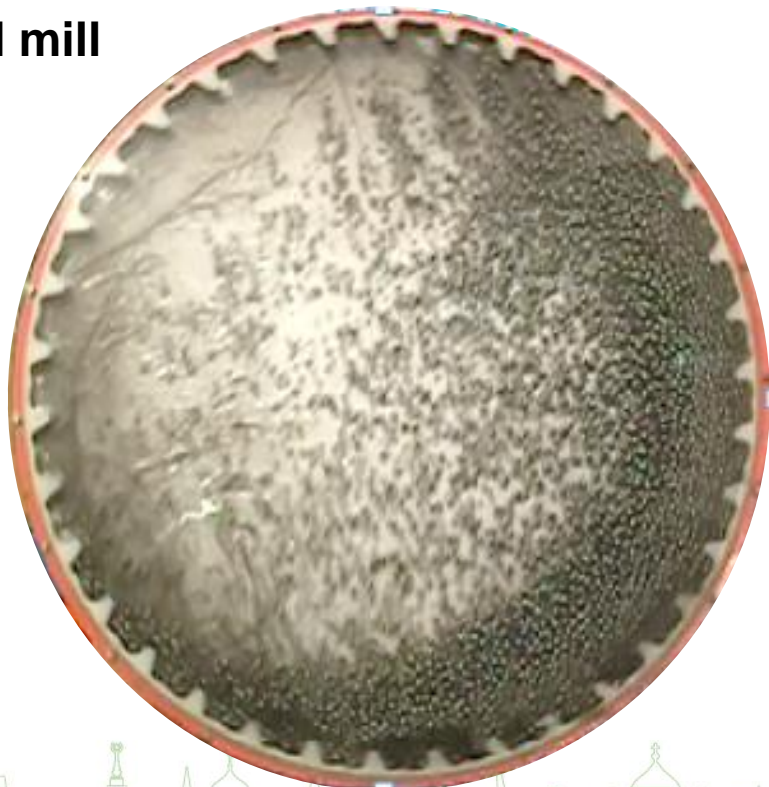
85% of critical speed; 25% filling

Liner design improvment

(Gol-E-Gohar iron ore SAG mill; new liner)

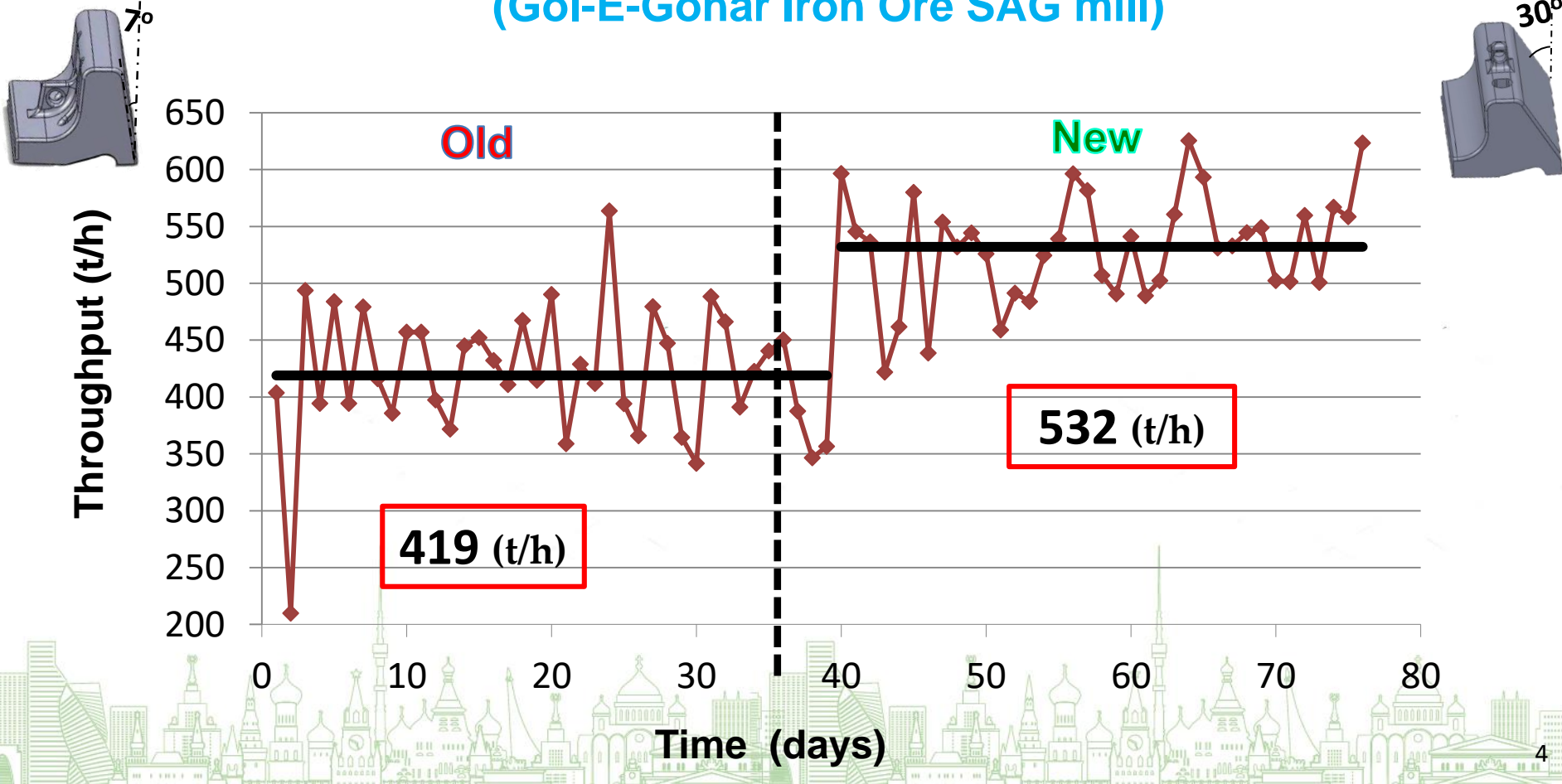


Model mill



85% of critical speed; 25% filling

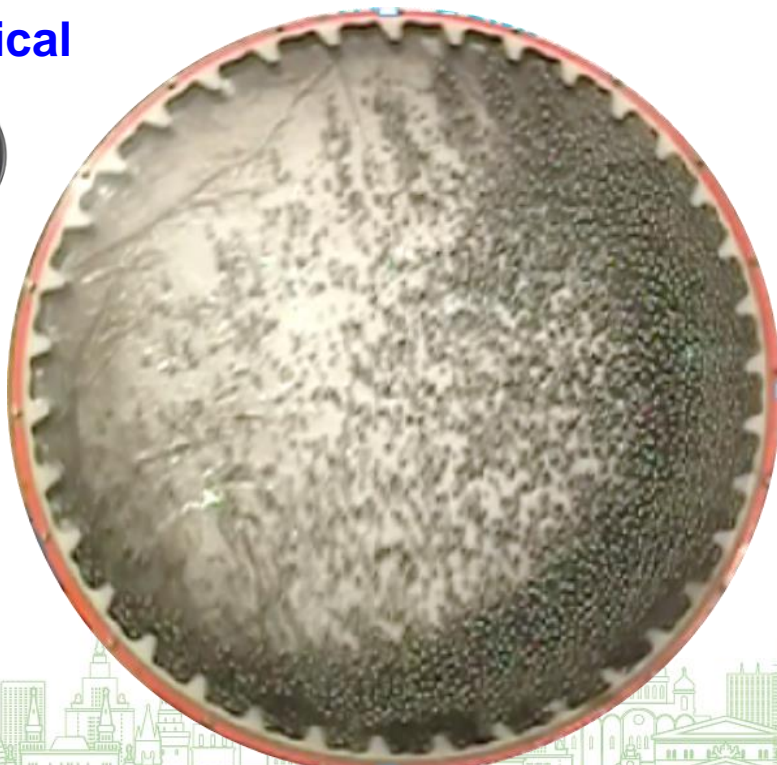
Effect of new liners on mill throughput (Gol-E-Gohar Iron Ore SAG mill)



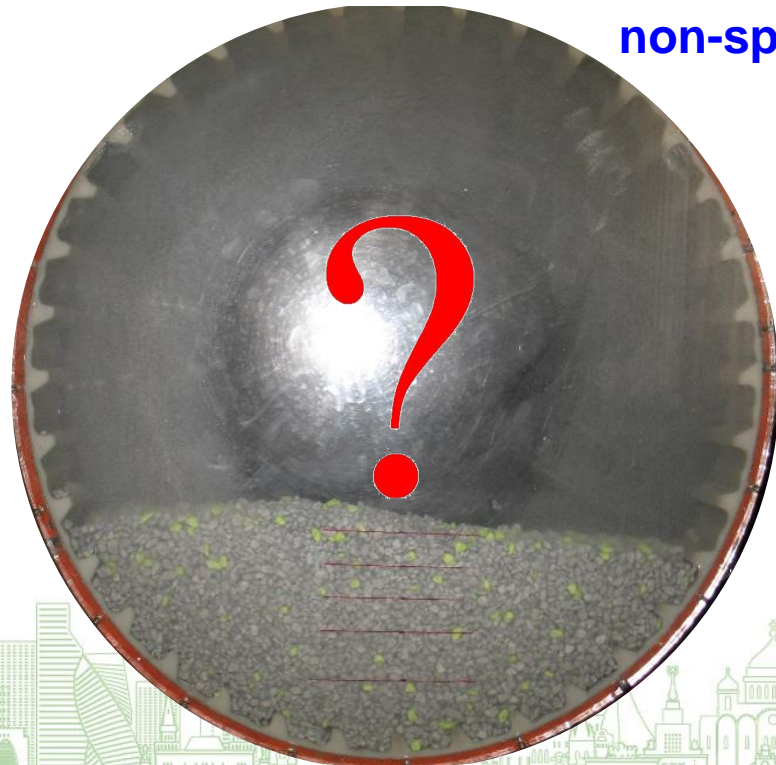
Is charge trajectory realistic?

What are the differences between charge trajectory of spherical and non-spherical particles?

Spherical



non-spherical



What are the differences between simulation of spherical and non-spherical particles movement?

Effect of shape on particle velocity



A hollow spherical shell



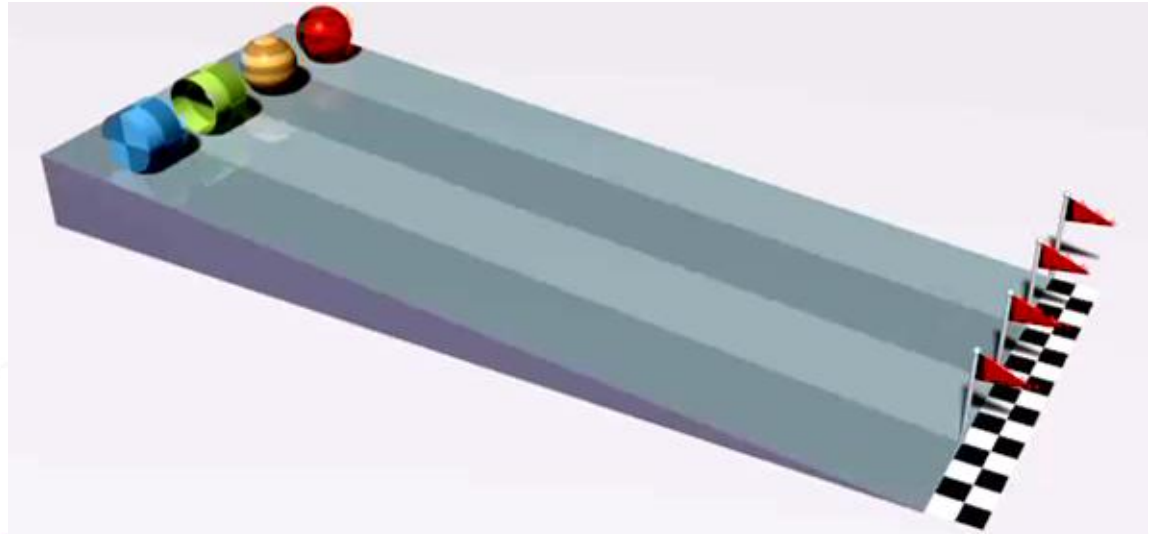
A solid ball



A ring

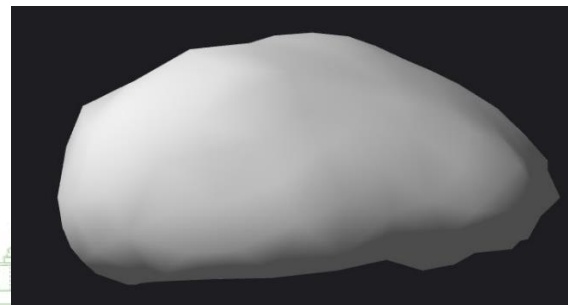
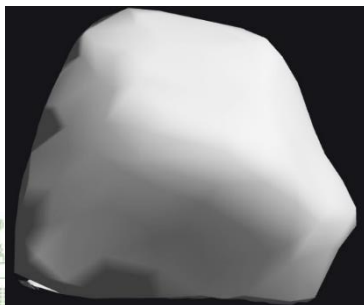


A solid cylinder





Shape representation by 3D scanning



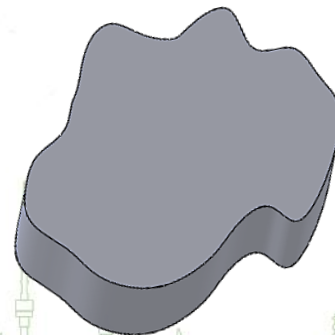
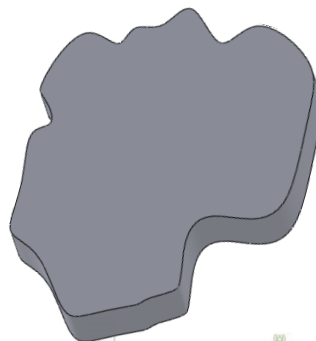
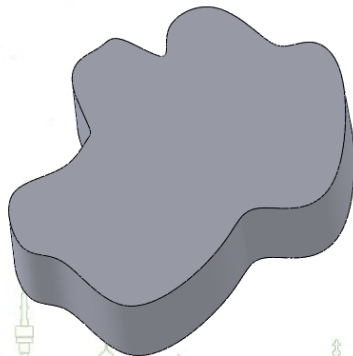
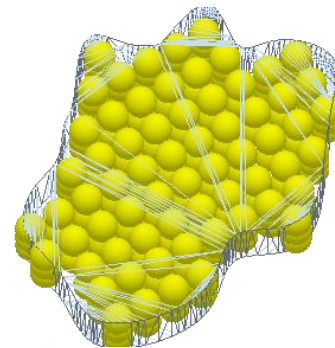
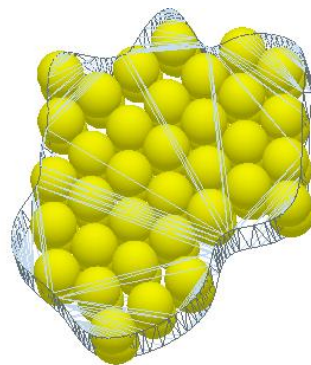
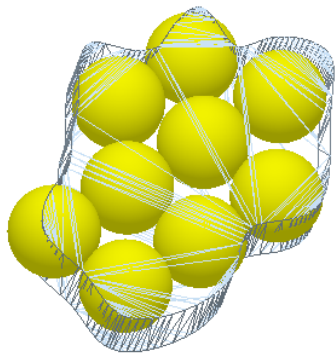
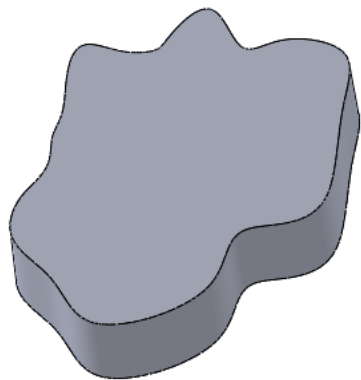
Regeneration of shapes by sphere packing

No. of spheres

9

70

198



More realistic mass and shape representation

Differences of simulation: Center of mass

Grain

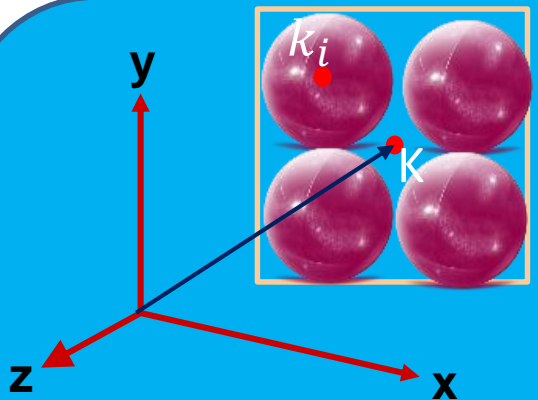


Diagram illustrating the calculation of the center of mass (K) for a grain, which is a collection of particles. The grain is shown as a cluster of four particles in a 3D coordinate system (x, y, z). The center of mass K is calculated as the weighted average of the positions of the particles, where the weight is the particle mass (m).

$$K = \frac{1}{m} * \sum_1^N (k_i * V * \rho)$$

Particle density	ρ	Particle volume	V
Grain mass	m	No. of particles	N
Particle position	k_i		

Particle

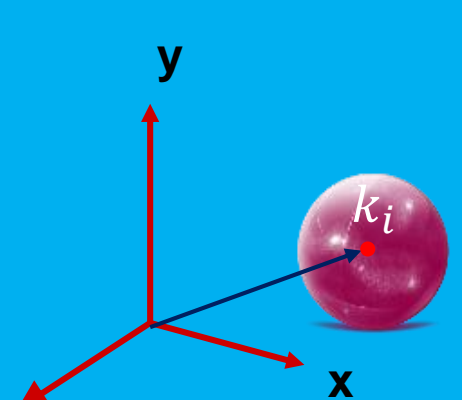
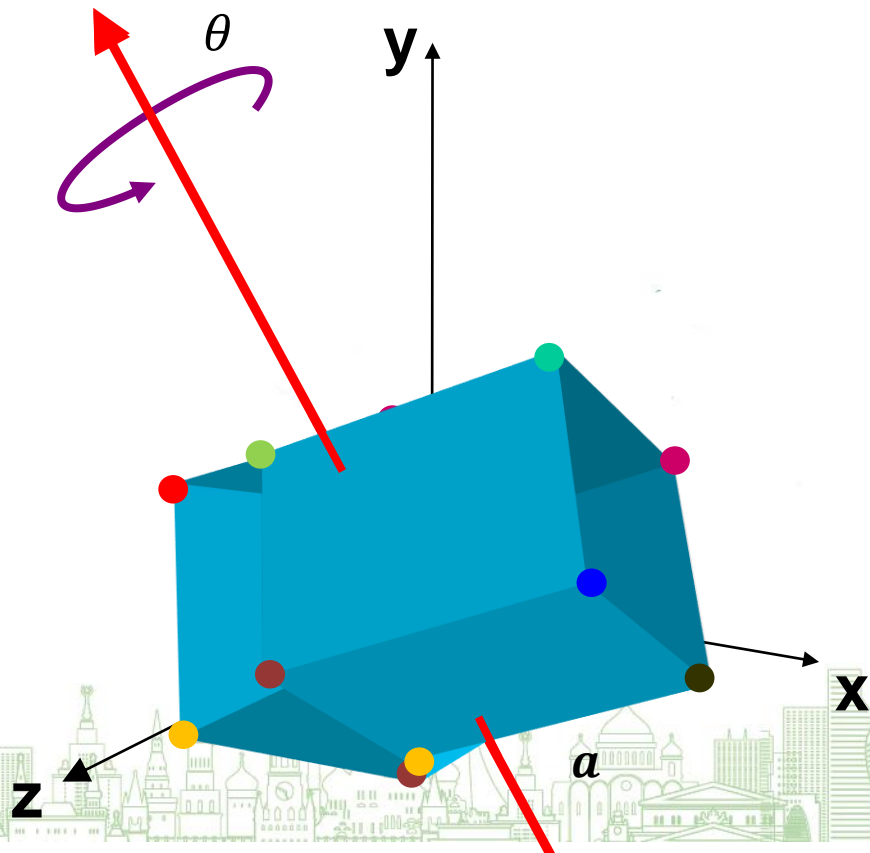


Diagram illustrating the center of mass (K) for a single particle. The particle is shown in a 3D coordinate system (x, y, z). The center of mass K is equal to the position vector k_i of the particle.

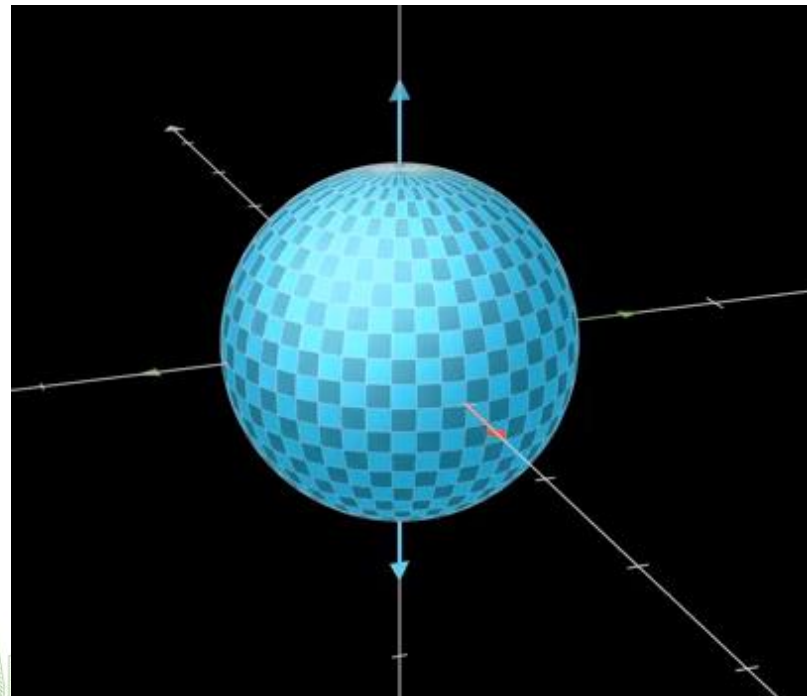
$$K = k_i$$

Differences of simulation: **Particle rotation**

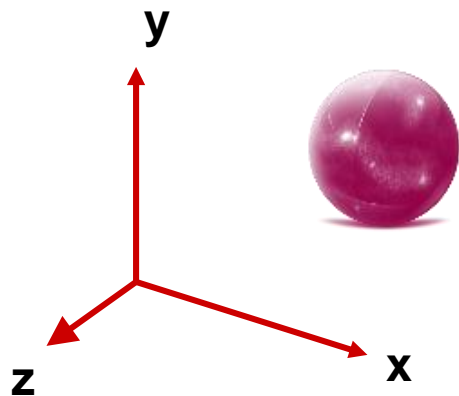
Non-spherical



Spherical

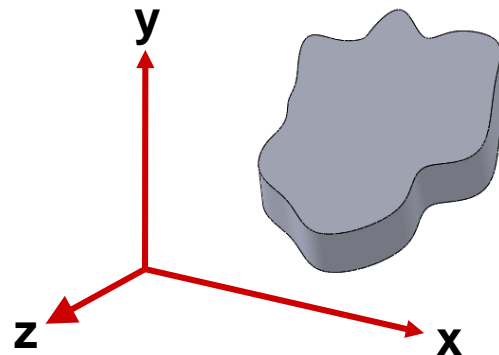


Differences of simulation: Inertia tensor



$$I = \begin{bmatrix} \frac{2}{5}mr^2 & 0 & 0 \\ 0 & \frac{2}{5}mr^2 & 0 \\ 0 & 0 & \frac{2}{5}mr^2 \end{bmatrix}$$

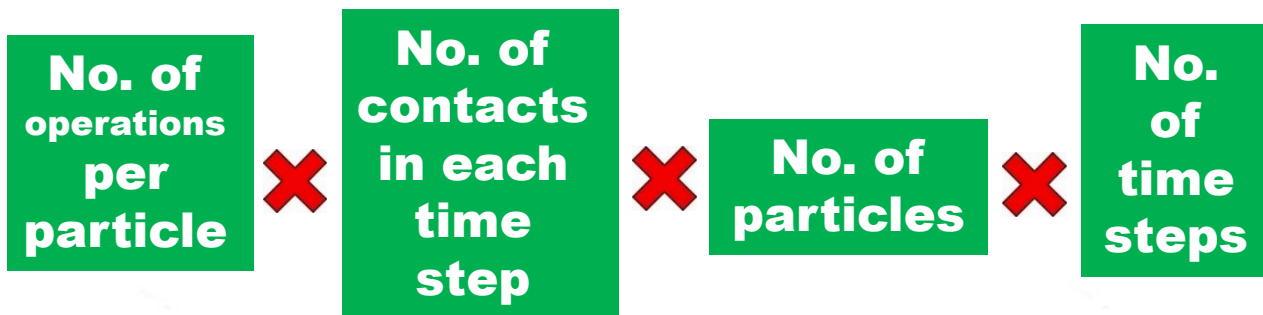
Sphere radius (r)
Sphere mass (m)



$$I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$



Differences of simulation: Number of operations for one second simulation of 2 million particles



Spherical 1000 × 5 × 2 M × 1 M = 1×10^{16}

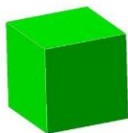
Non-spherical 74500 × 70 × 2 M × 1 M = 1×10^{19}

Effect particle shape on charge trajectory

Tetrahedron



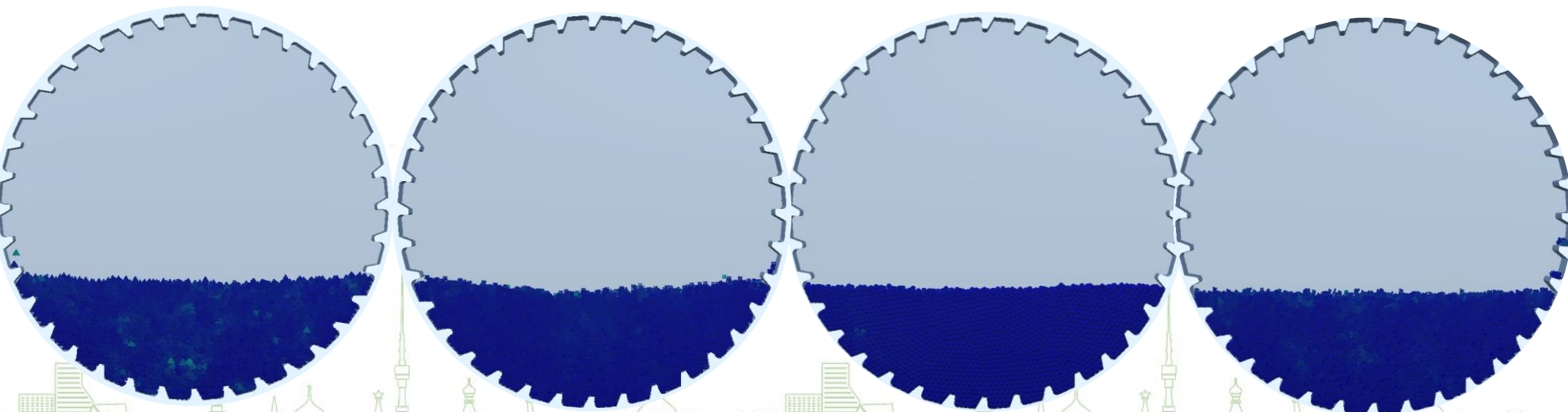
Cubic



Spherical



Ore

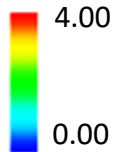


25% filling

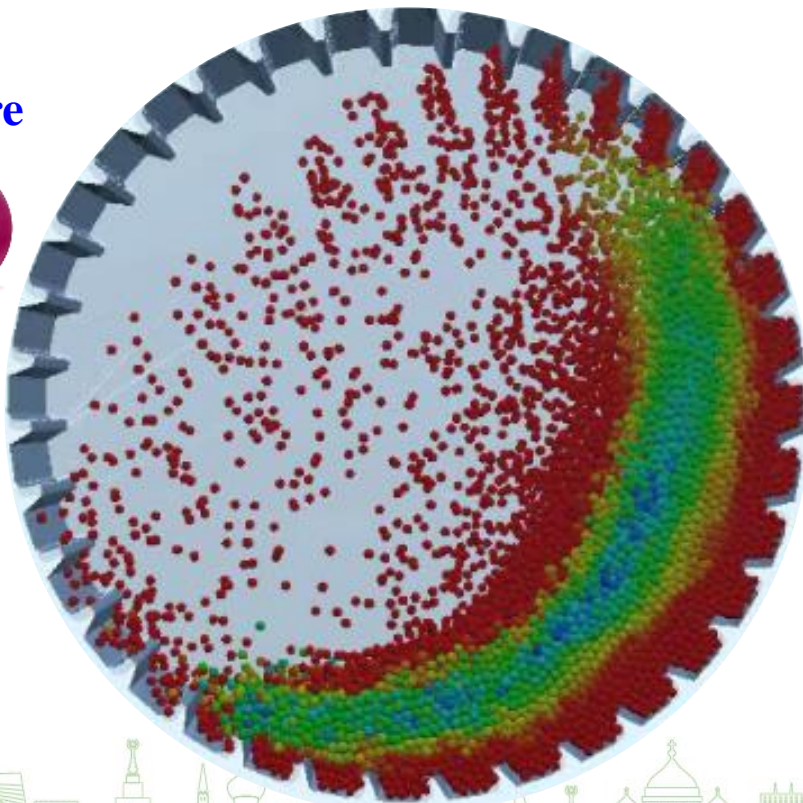
Effect particle shape on charge trajectory



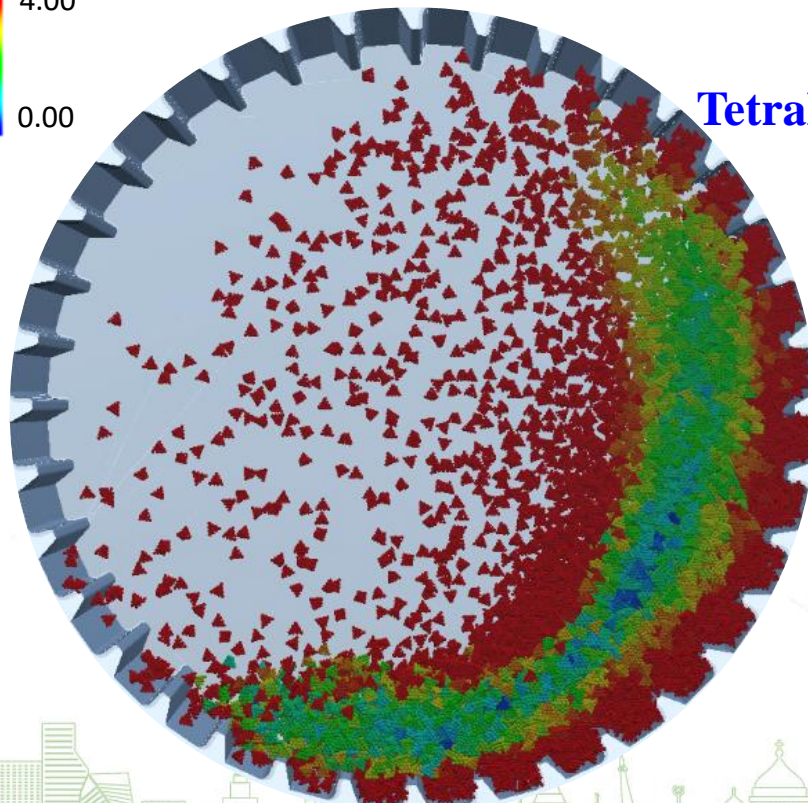
Velocity (m/s)



Sphere



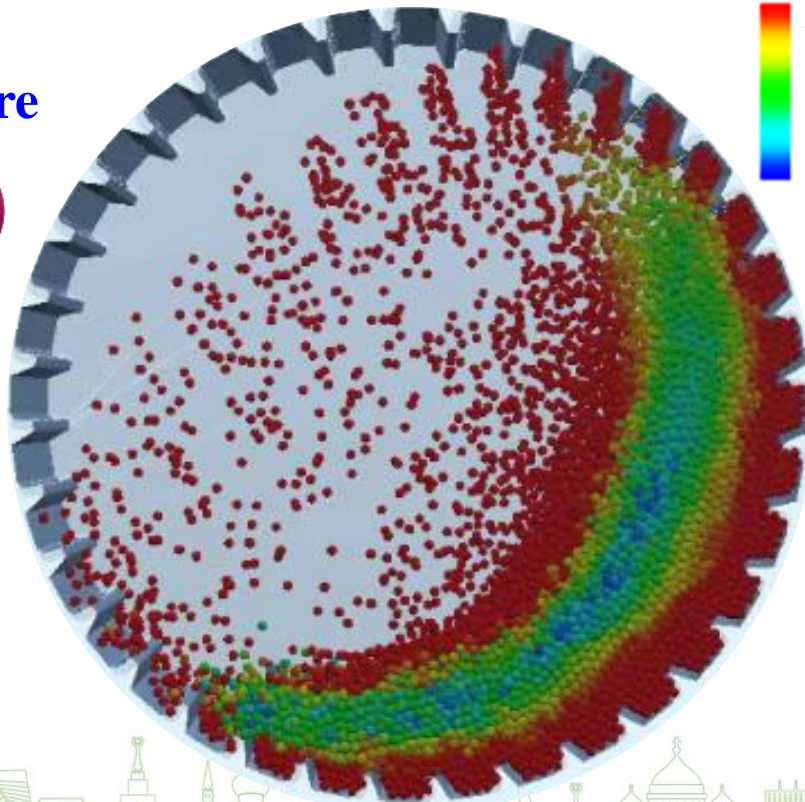
Tetrahedron



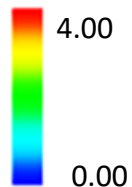
85% of critical speed; 25% filling

Effect particle shape on charge trajectory

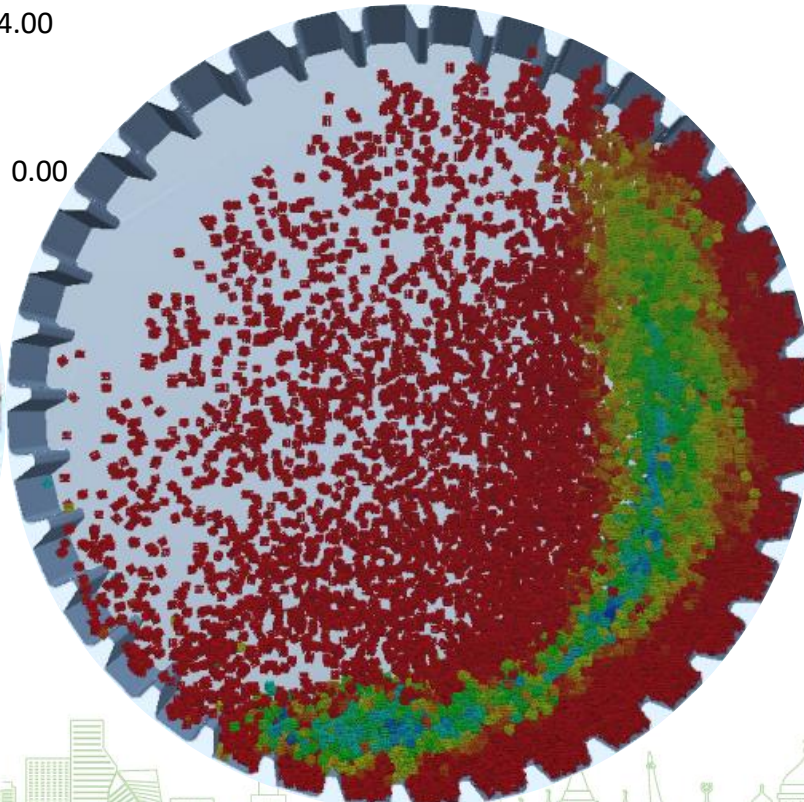
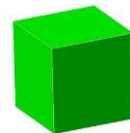
Sphere



Velocity (m/s)



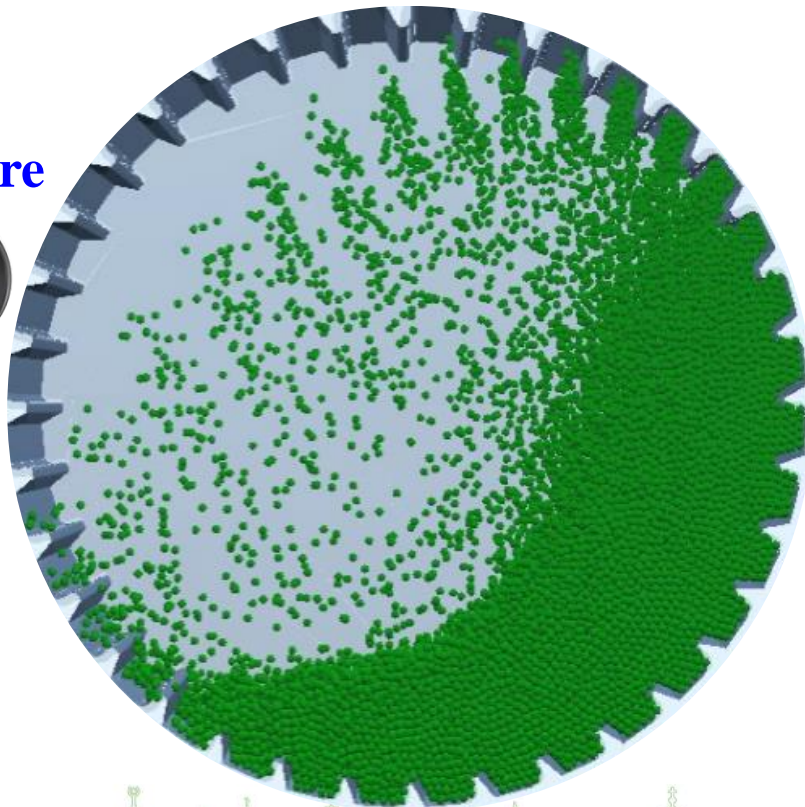
Cube



85% of critical speed; 25% filling

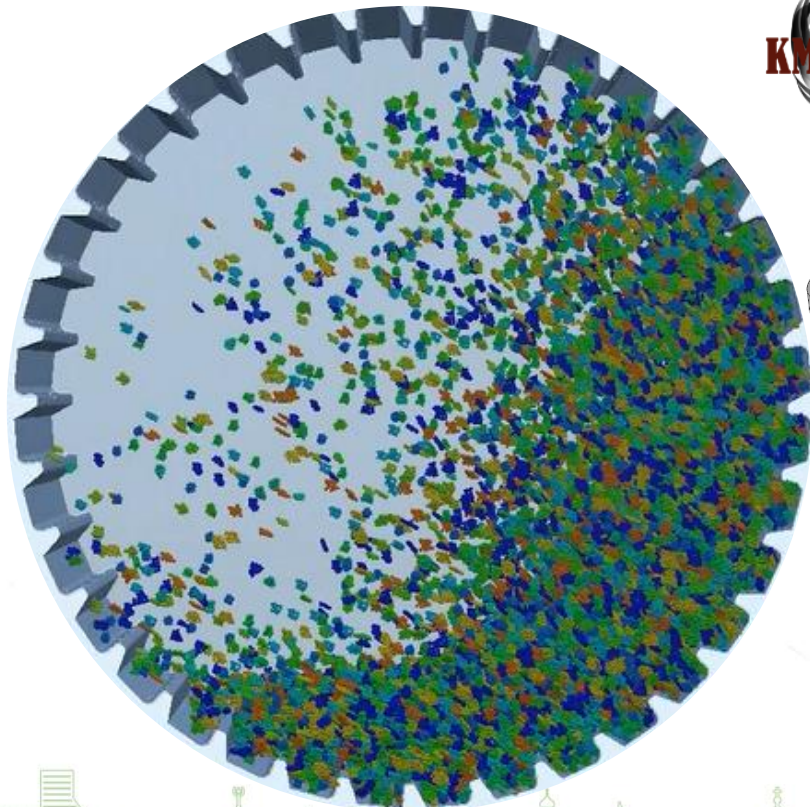
Effect particle shape on charge trajectory

Sphere



KNPC DEM

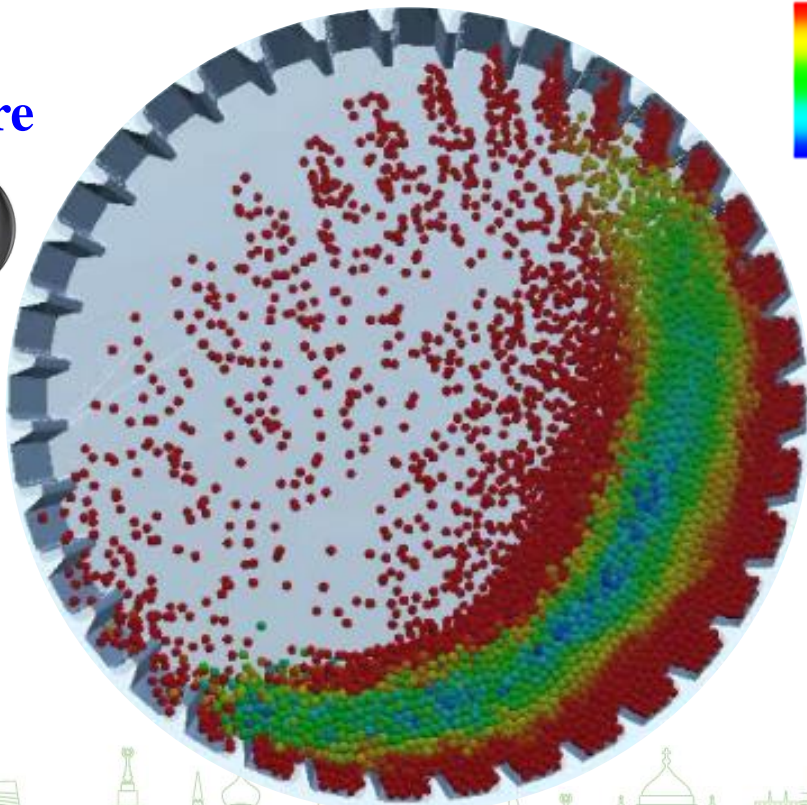
Ore



Colors indicate particles shape (10 types)
85% of critical speed; 25% filling

Effect particle shape on charge trajectory

Sphere



Velocity (m/s)

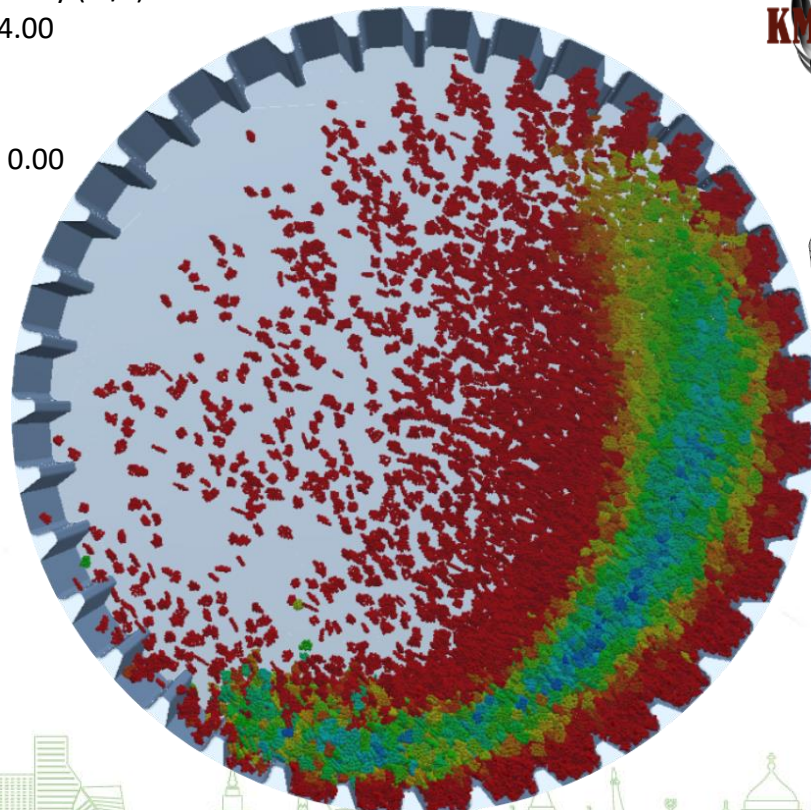
4.00

0.00



KMPC DEM

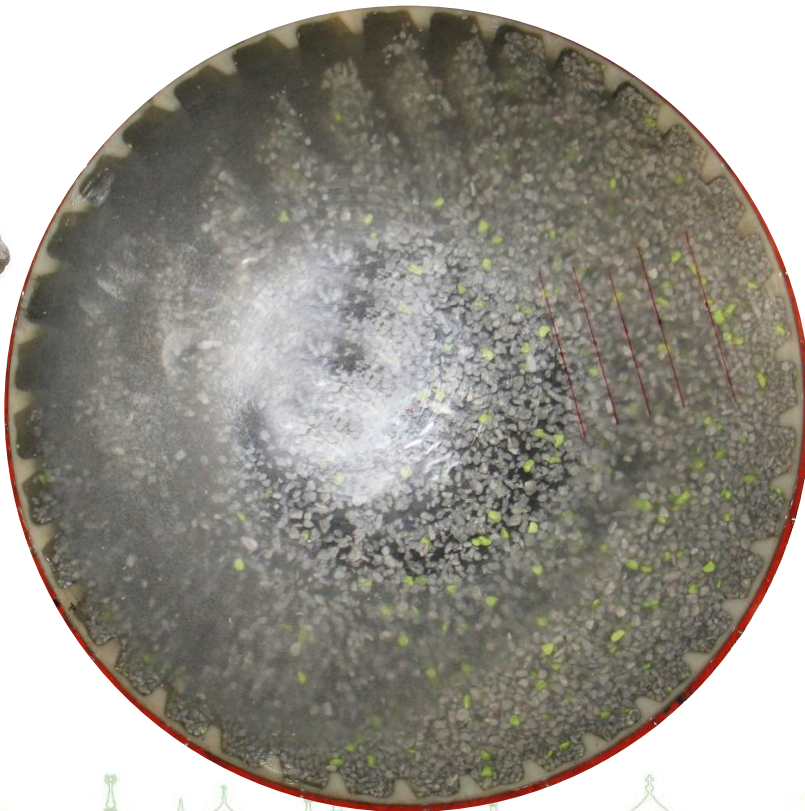
Ore



85% of critical speed; 25% filling

Effect particle shape on charge trajectory

Ore



IMPC DEMO

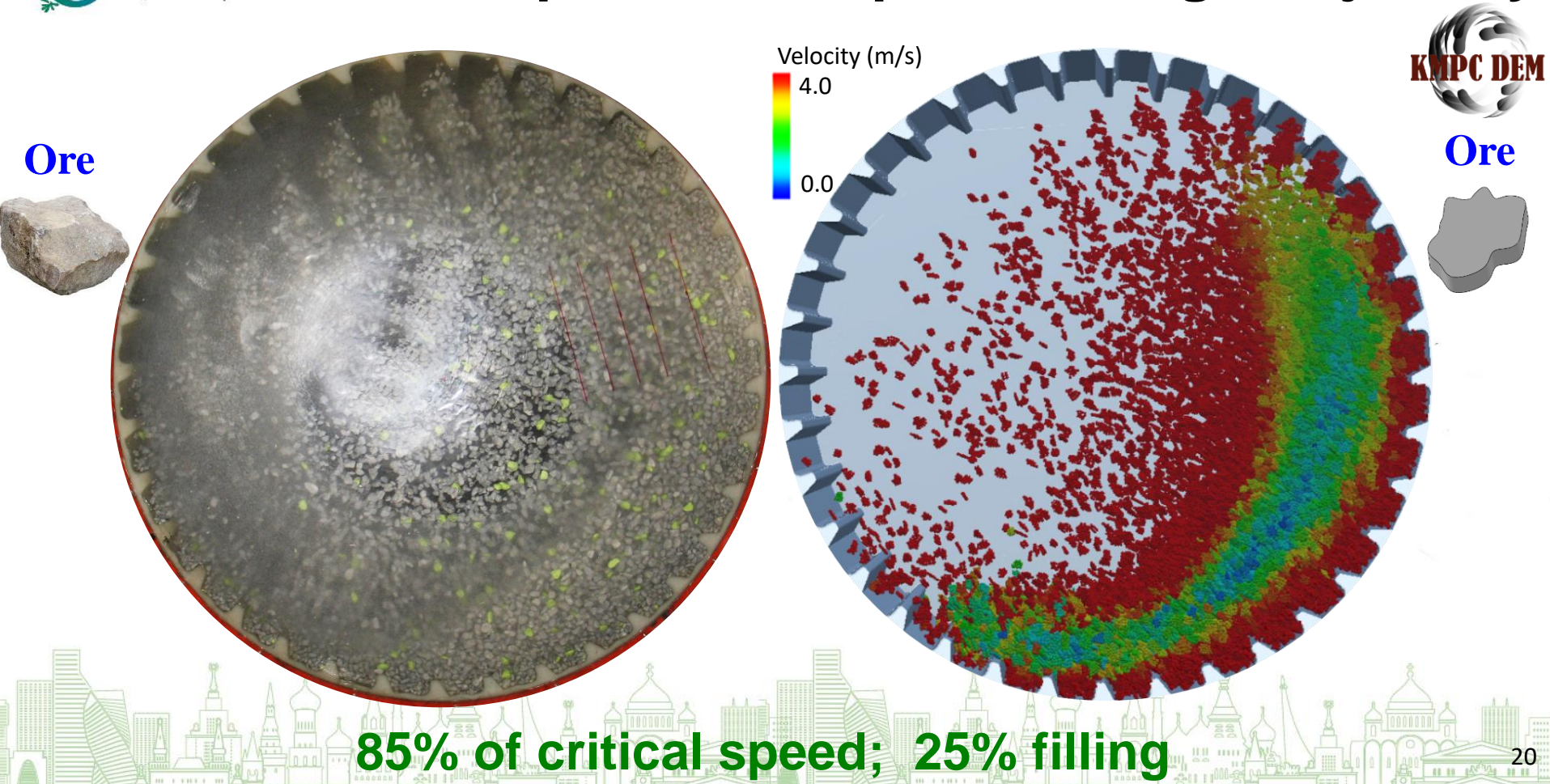
Ore



Colors indicate
particles shape
(10 types)

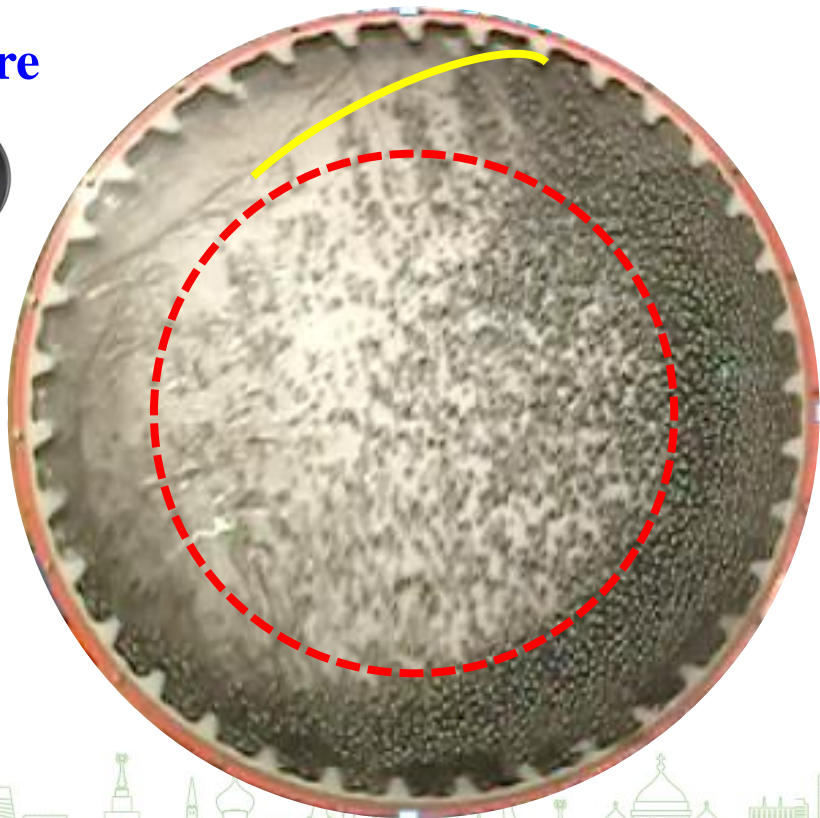
85% of critical speed; 25% filling

Effect particle shape on charge trajectory

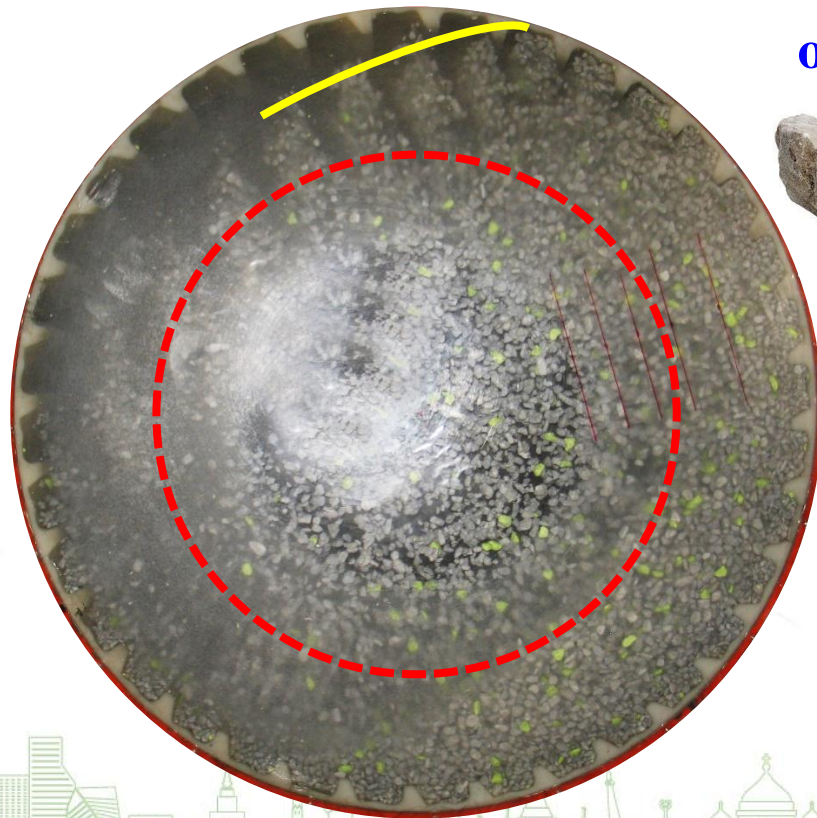


Effect particle shape on charge trajectory

Sphere



ore



85% of critical speed; 25% filling

Conclusions

- **Moving from spheres to real shape particles significantly impacts charge trajectory.**
- **Shoulder location in the case of ore is close to 12 o'clock position compared to other shapes.**
- **Simulation time could increase 1000 times for non-spherical particles compared to spherical.**

Acknowledgements

- **Gol-E-Gohar Mining and Industrial Company**
- **Sarcheshmeh copper complex**
- **Shahid Bahonar University of Kerman**

