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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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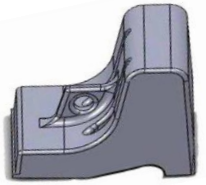
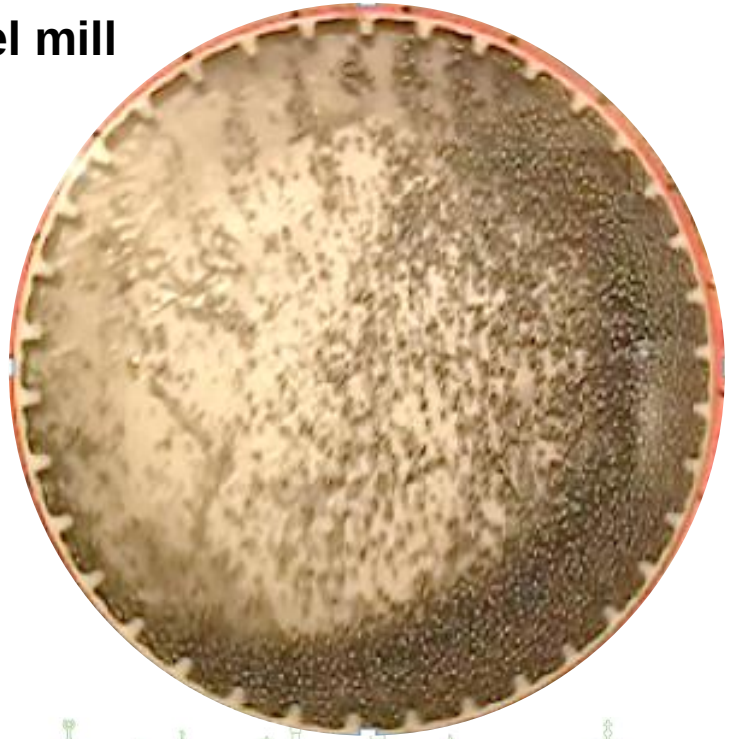
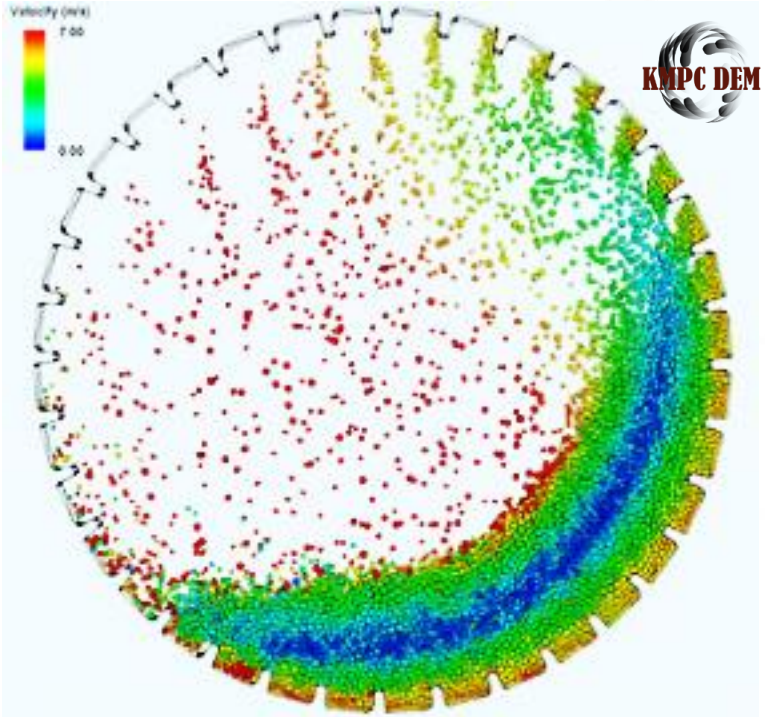
Charge trajectory

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



Model mill

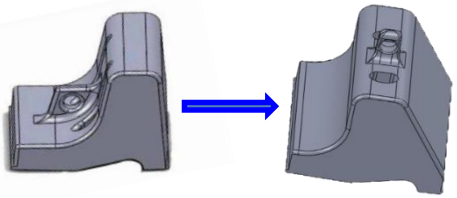




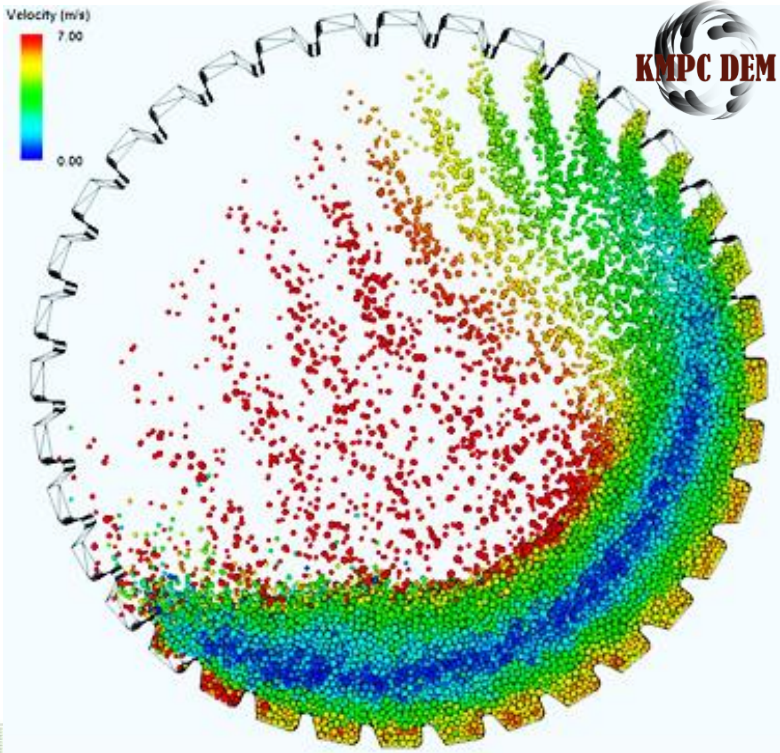
85% of critical speed; 25% filling

Liner design improvment

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



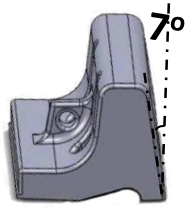
Model mill

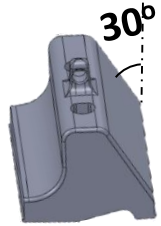


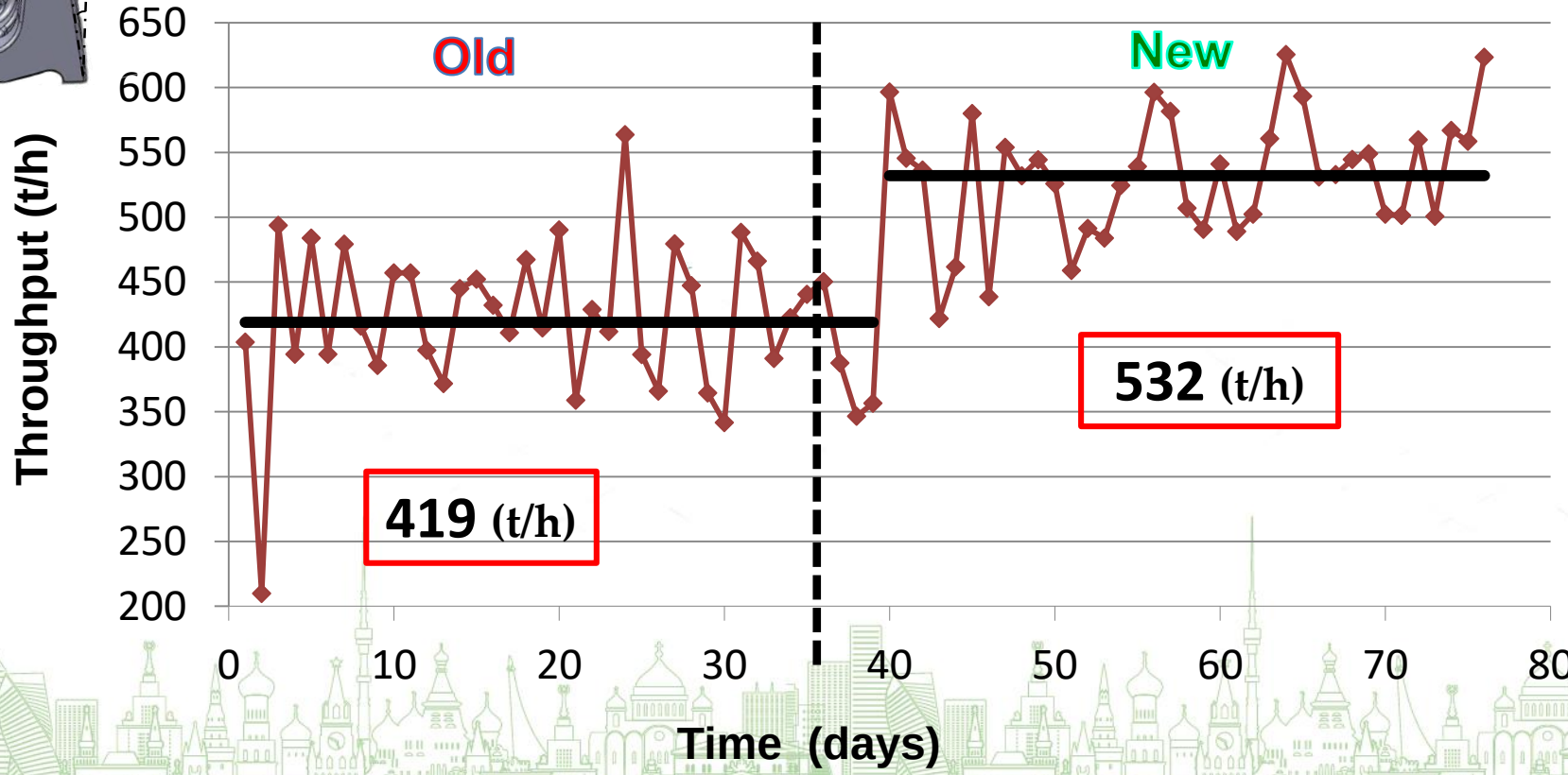
85% of critical speed; 25% filling

Effect of new liners on mill throughput

(Gol-E-Gohar Iron Ore SAG mill)



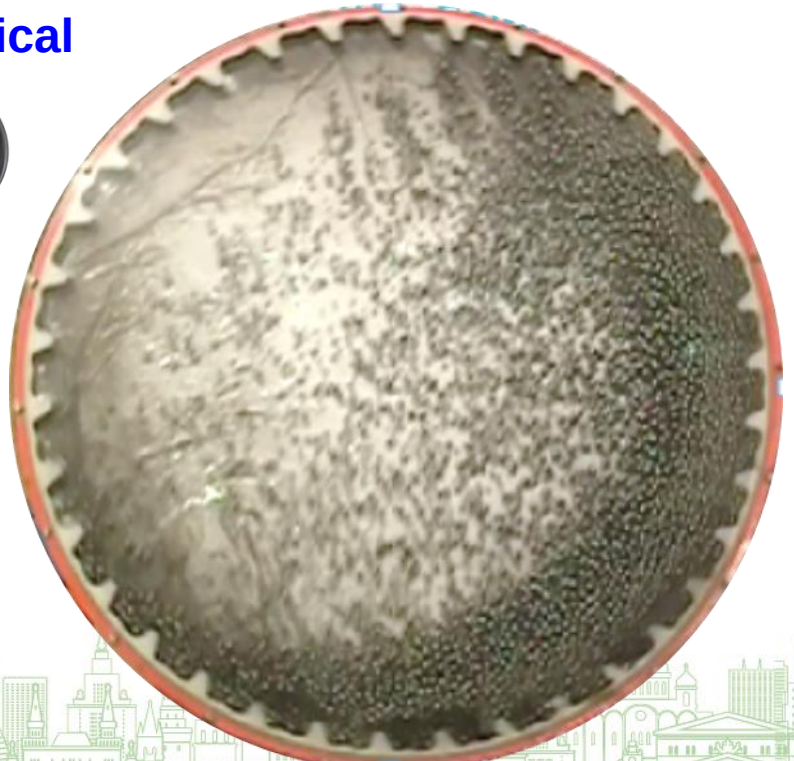




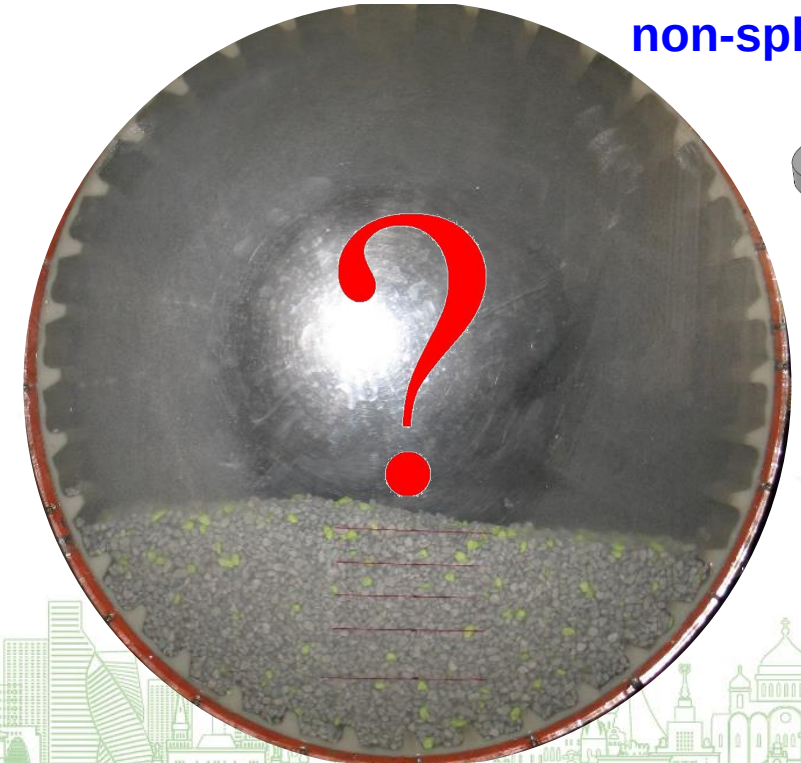
Is charge trajectory realistic?

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

Spherical



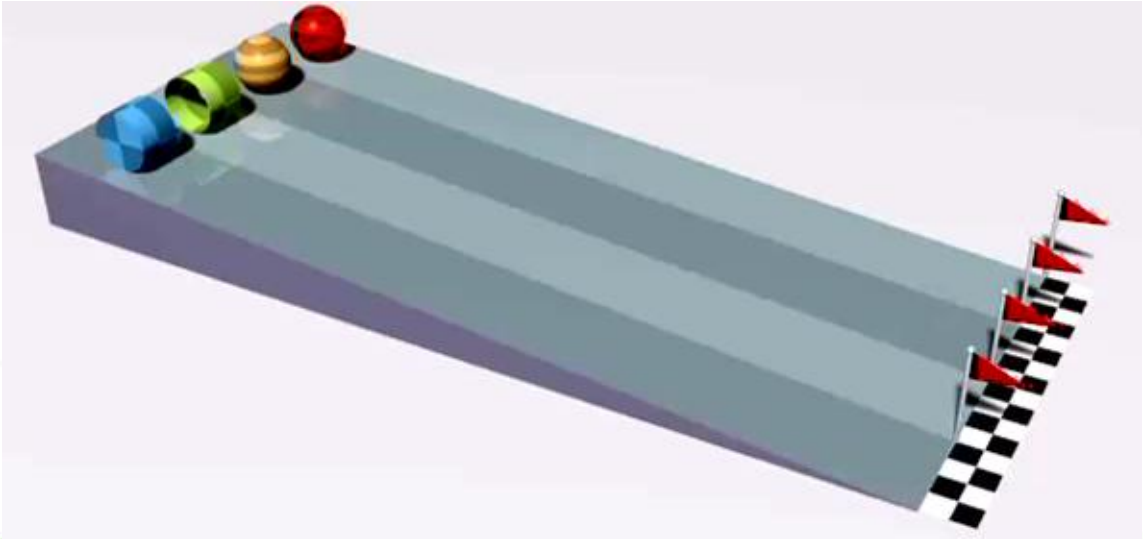
non-spherical



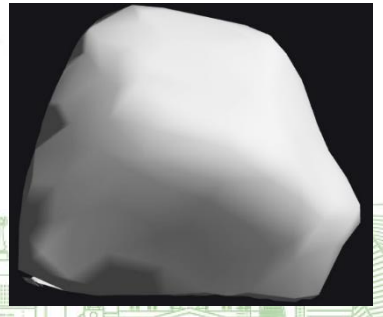
What are the differences between simulation of spherical and non-spherical particles movement?

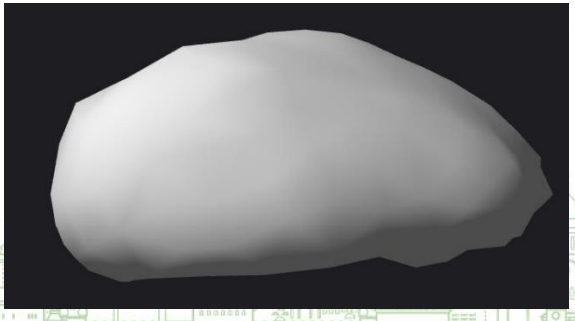
Effect of shape on particle velocity

- A hollow spherical shell
- A solid ball
- A ring
- A solid cylinder

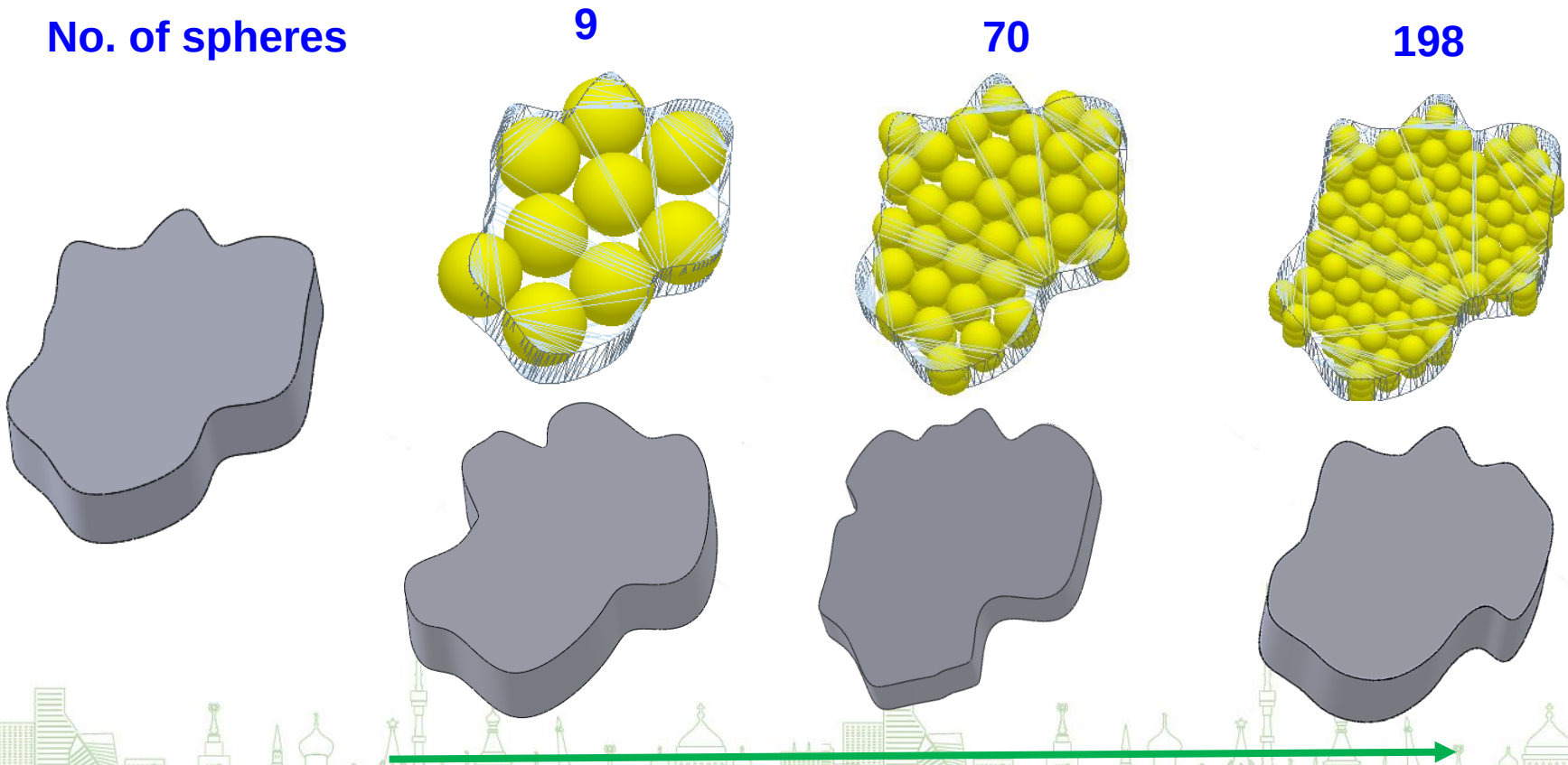


Shape represention by 3D scanning



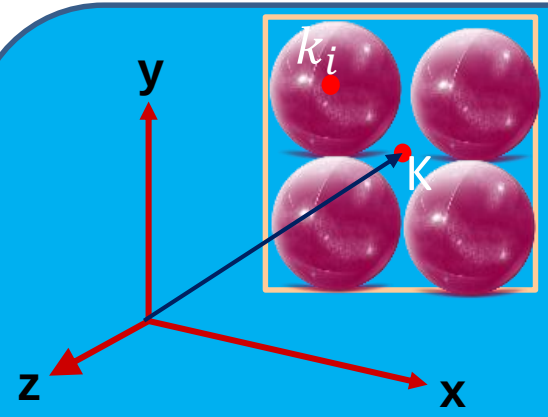


Regeneration of shapes by sphere packing



Differences of simulation: Center of mass

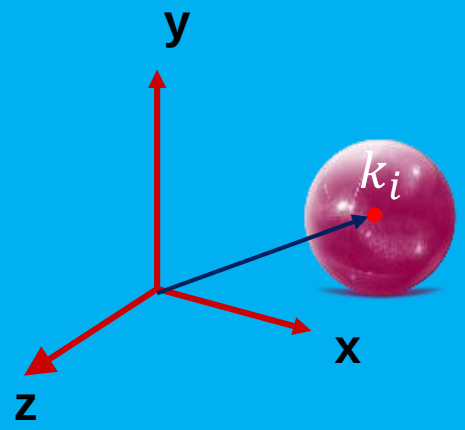
Grain



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

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

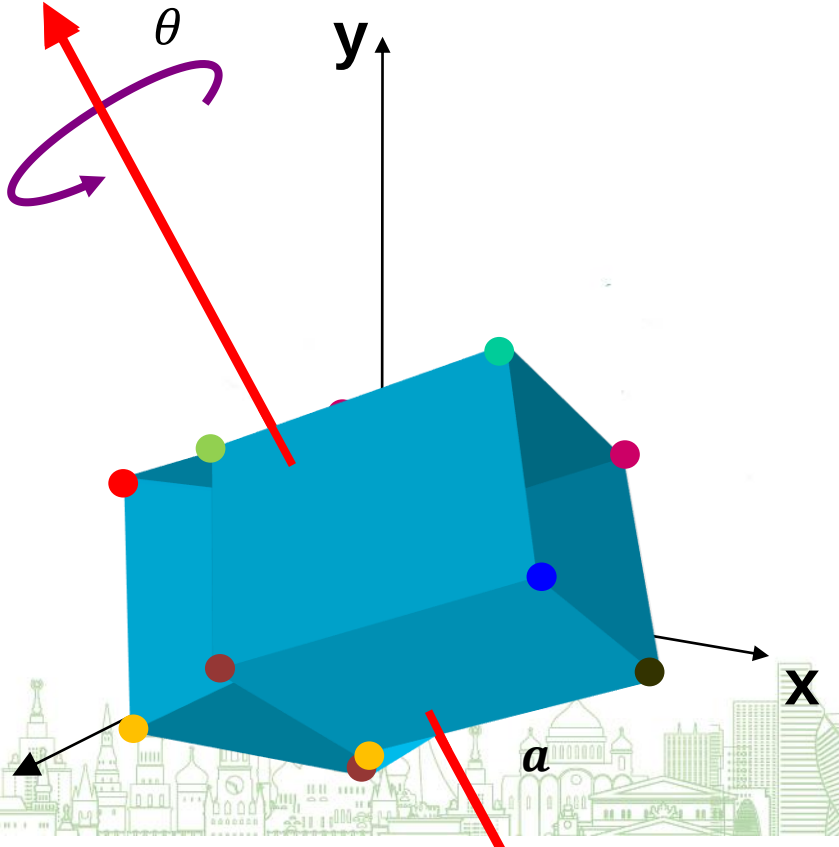
Particle



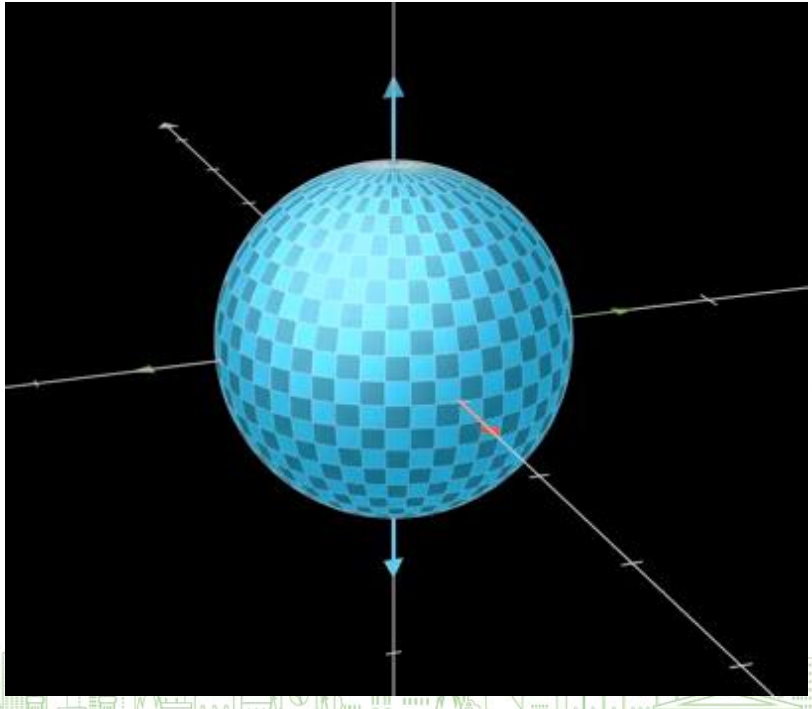
$K = k_i$

Differences of simulation: Particle rotation

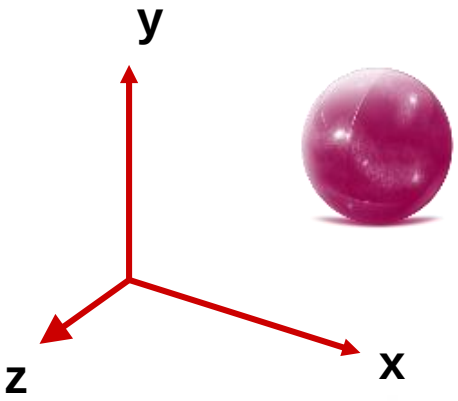
Non-spherical

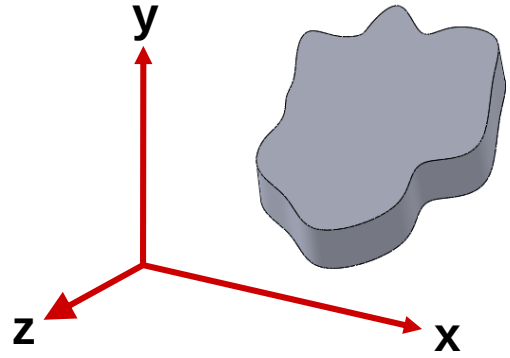


Spherical



Differences of simulation: Inertia tensor



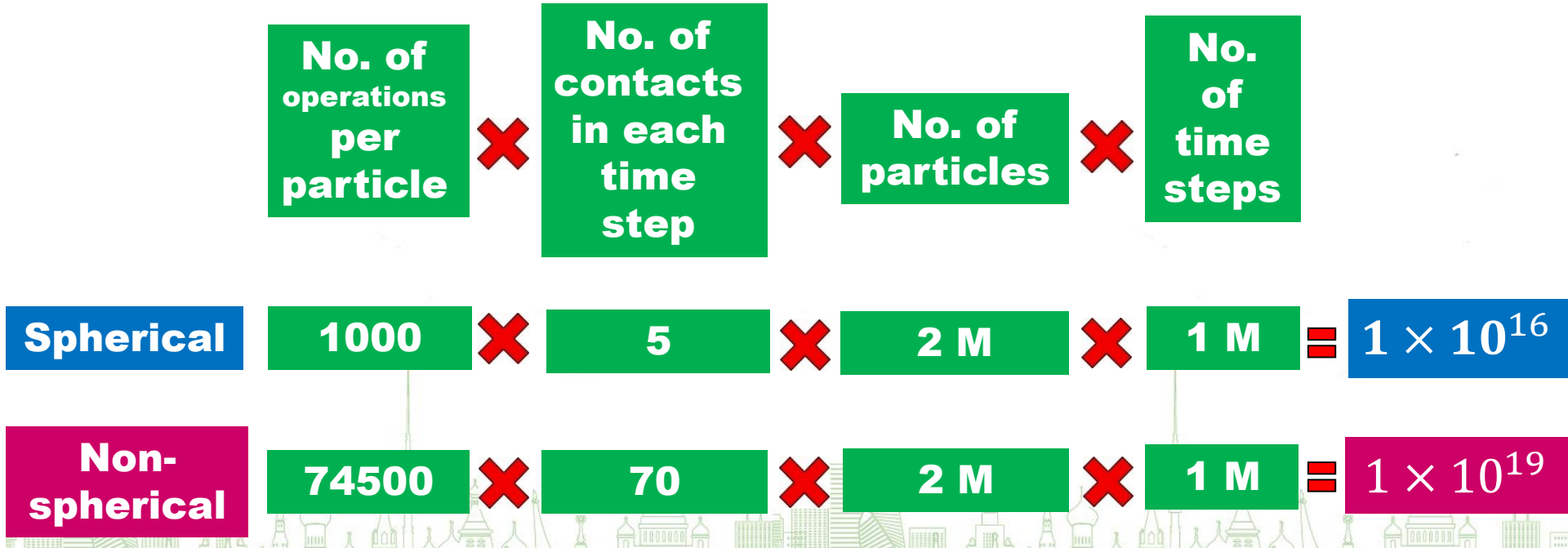


$$I = \begin{bmatrix} \frac{2}{5}mr^2 & 0 & 0 \\ 0 & \frac{2}{5}mr^2 & 0 \\ 0 & 0 & \frac{2}{5}mr^2 \end{bmatrix}$$

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



Effect particle shape on charge trajectory

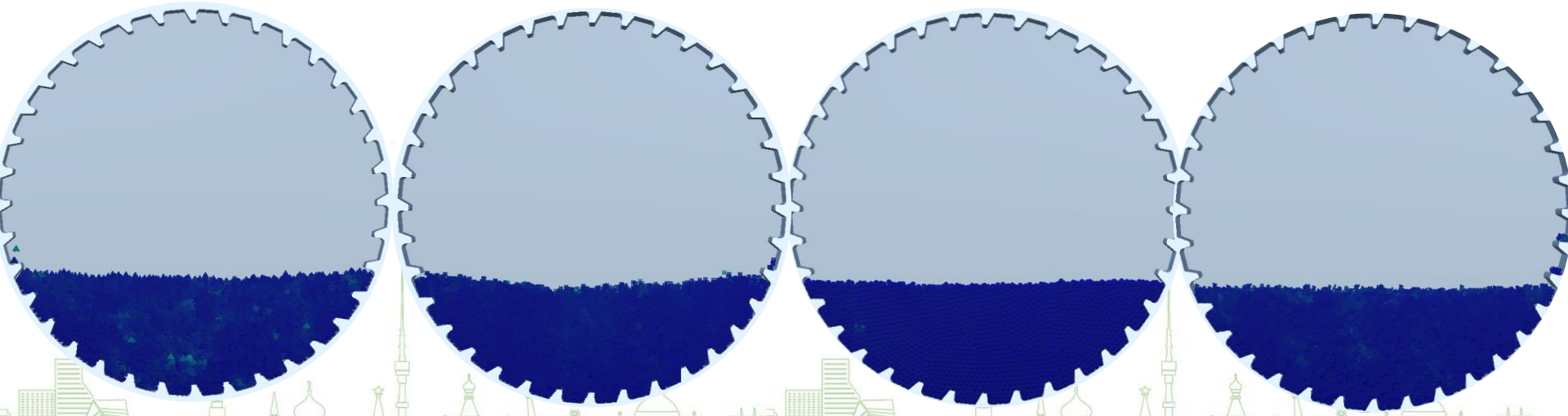
KMPC DEM

Tetrahedron

Cubic

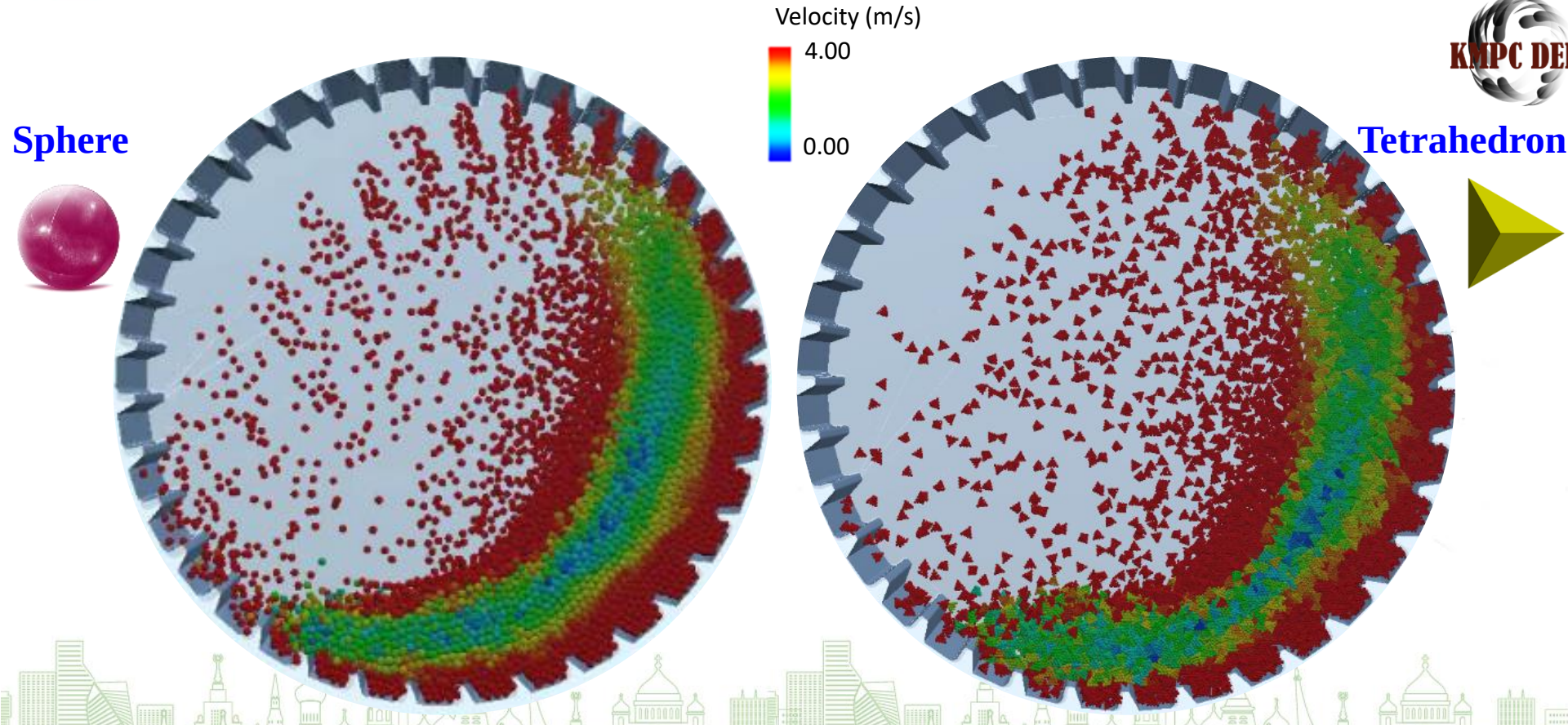
Spherical

Ore



25% filling

Effect particle shape on charge trajectory



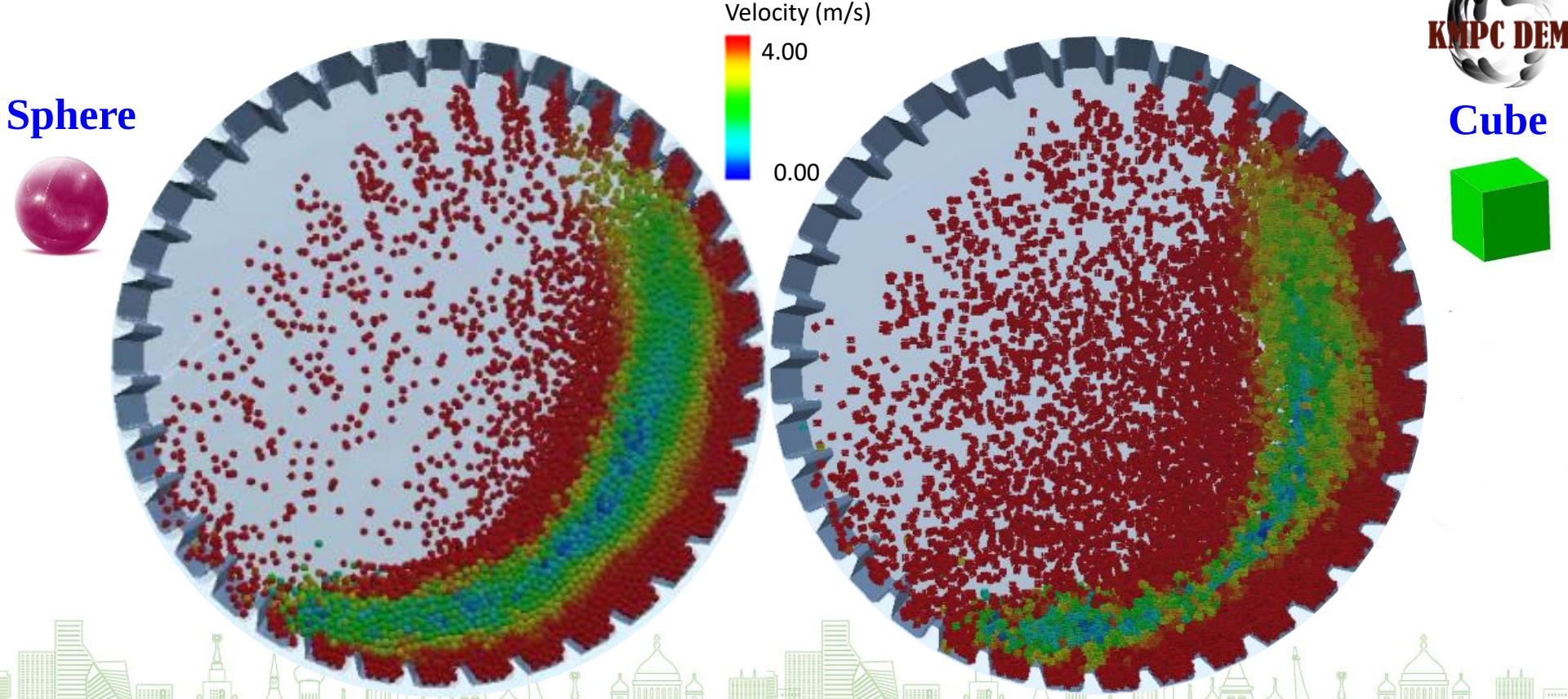
85% of critical speed; 25% filling

Effect particle shape on charge trajectory

KMPC DEM

Sphere

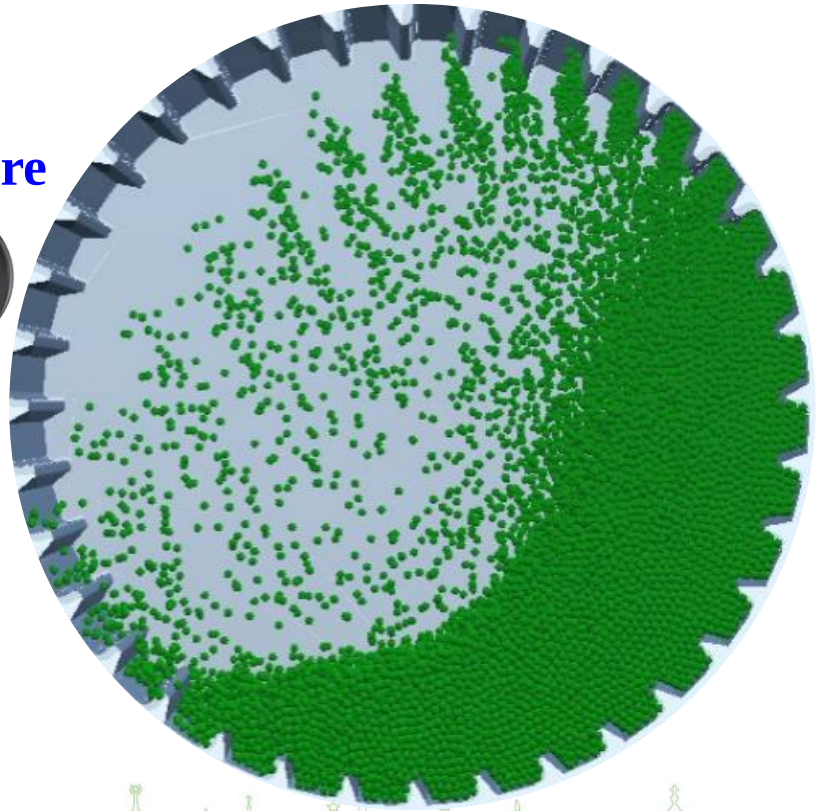
Cube

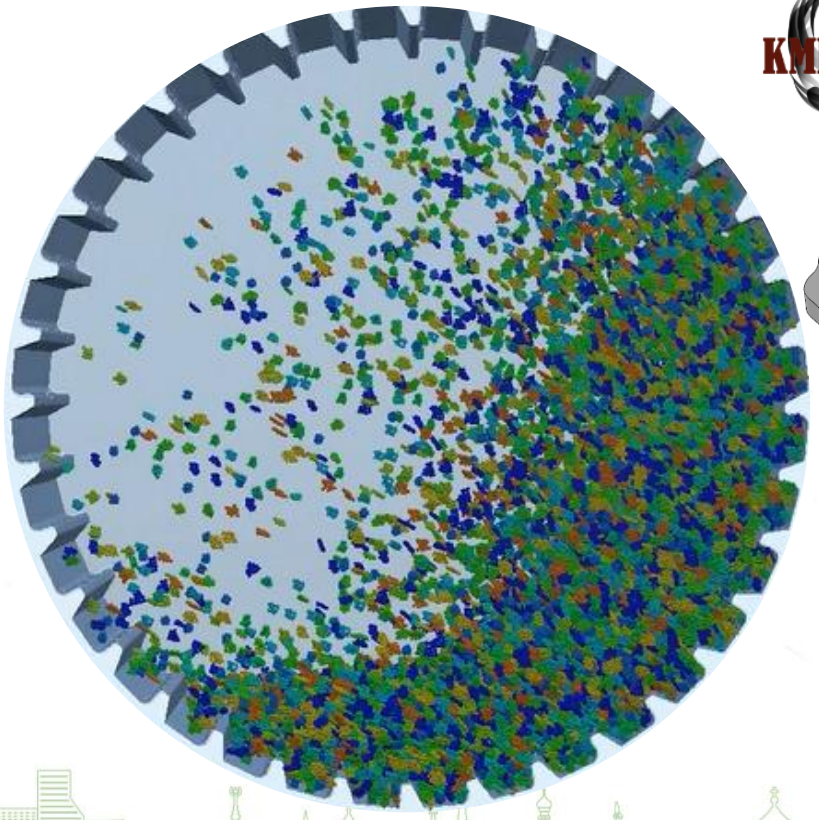


85% of critical speed; 25% filling

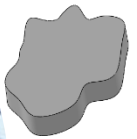
Effect particle shape on charge trajectory

Sphere





Ore



Colors indicate particles shape (10 types)

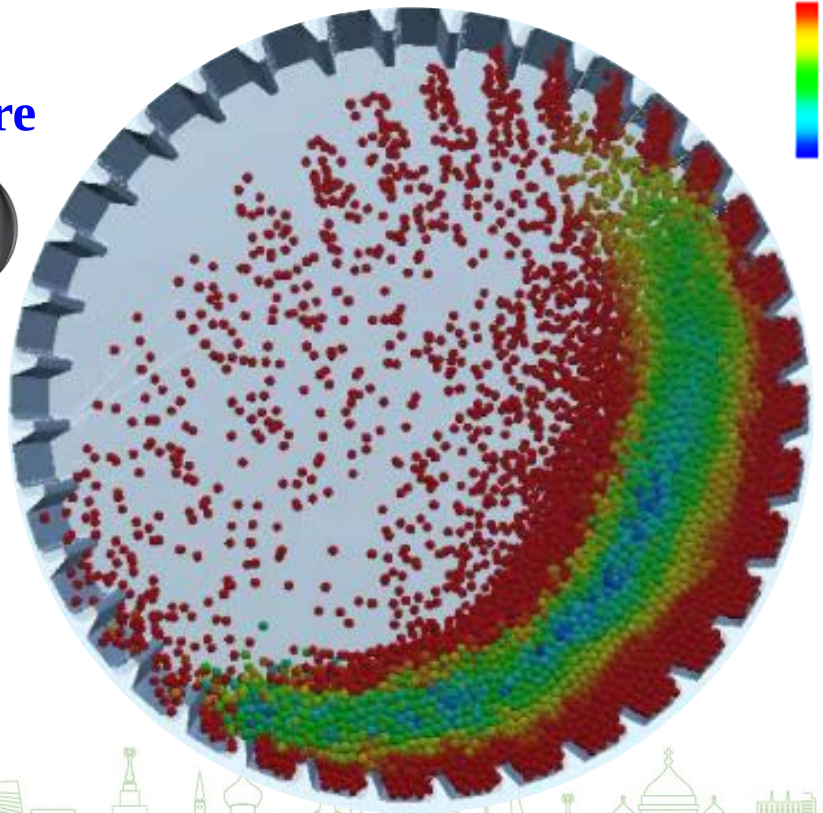
85% of critical speed; 25% filling

Effect particle shape on charge trajectory

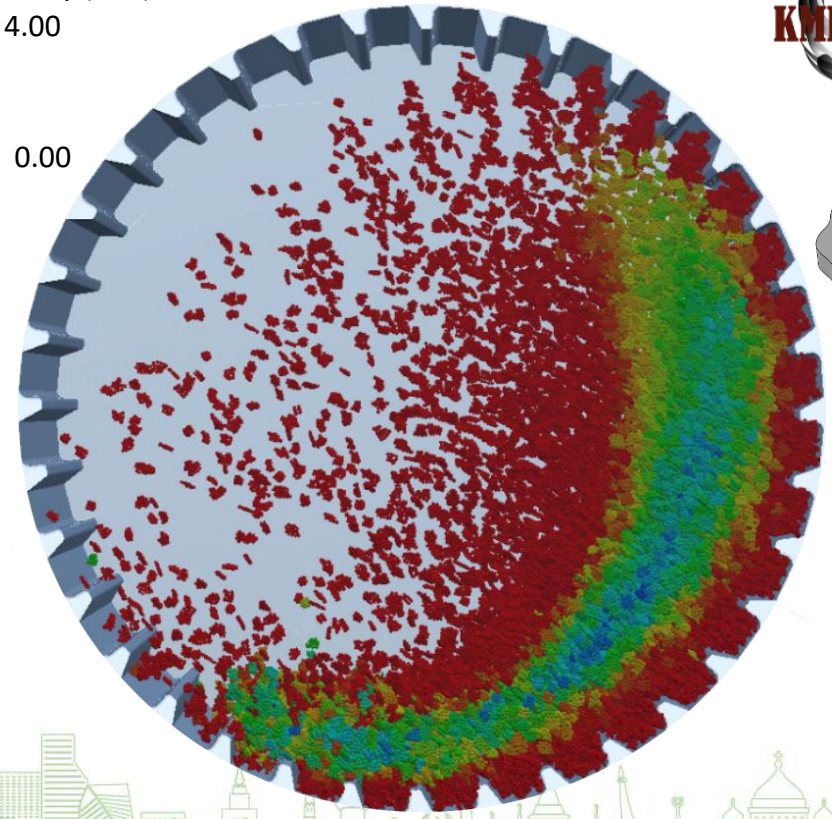
KMPC DEM

Velocity (m/s)
4.00
0.00

Sphere



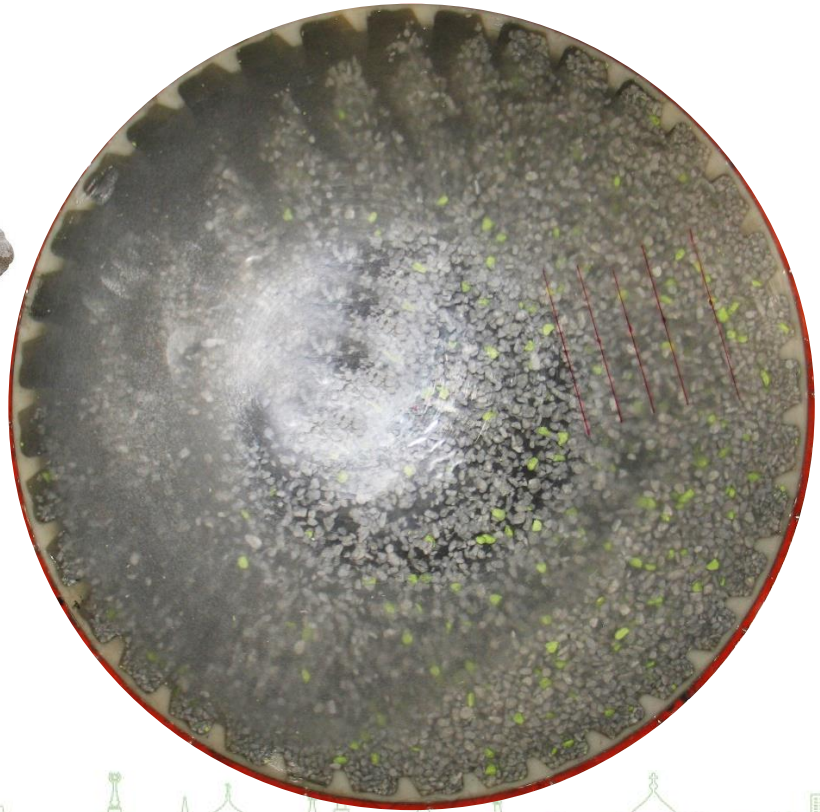
Ore

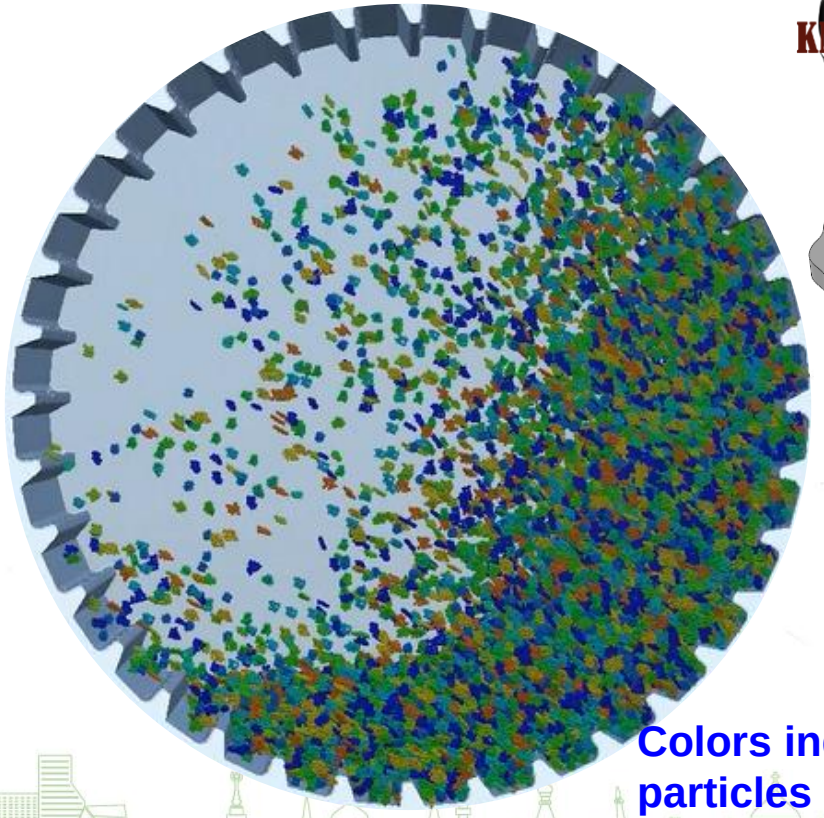


85% of critical speed; 25% filling

Effect particle shape on charge trajectory

Ore





Ore

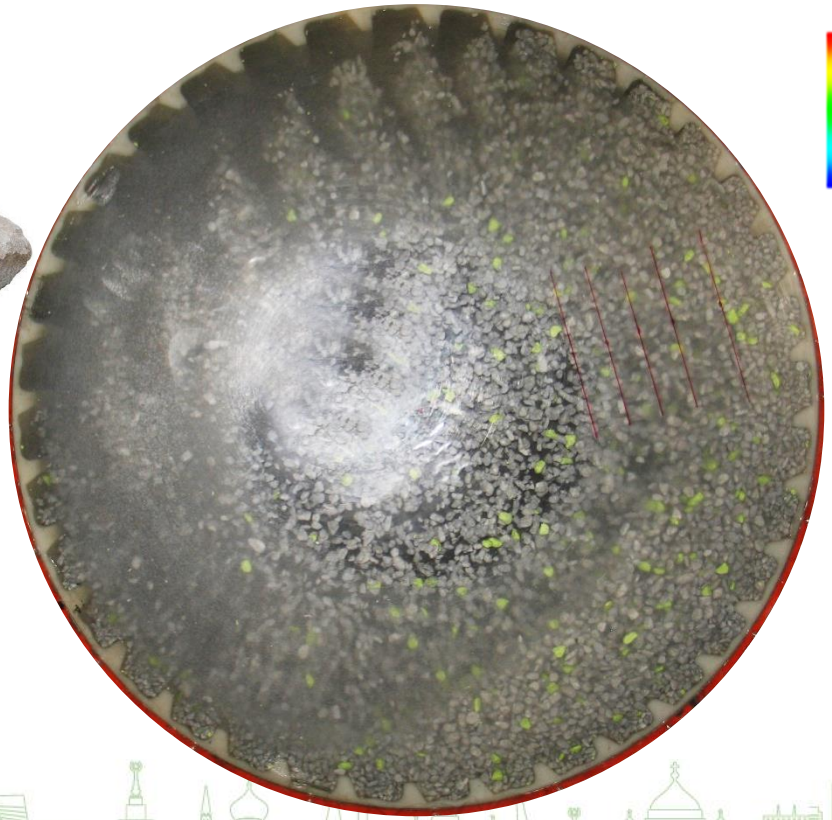
Colors indicate particles shape (10 types)

85% of critical speed; 25% filling

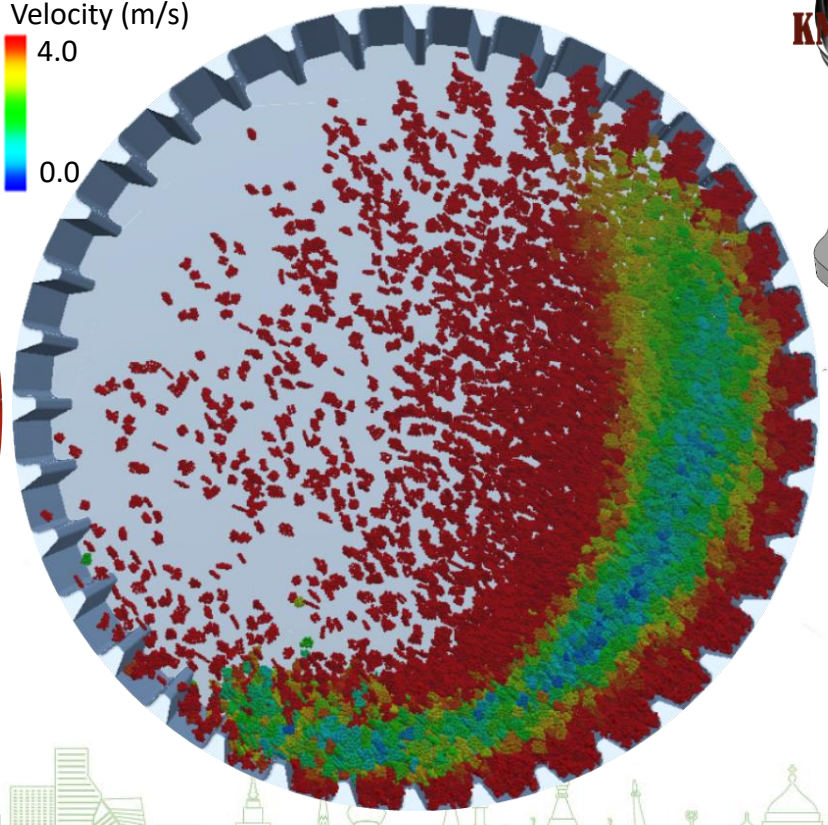
Effect particle shape on charge trajectory

KMPC DEM

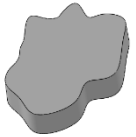
Ore



Velocity (m/s)
4.0
0.0



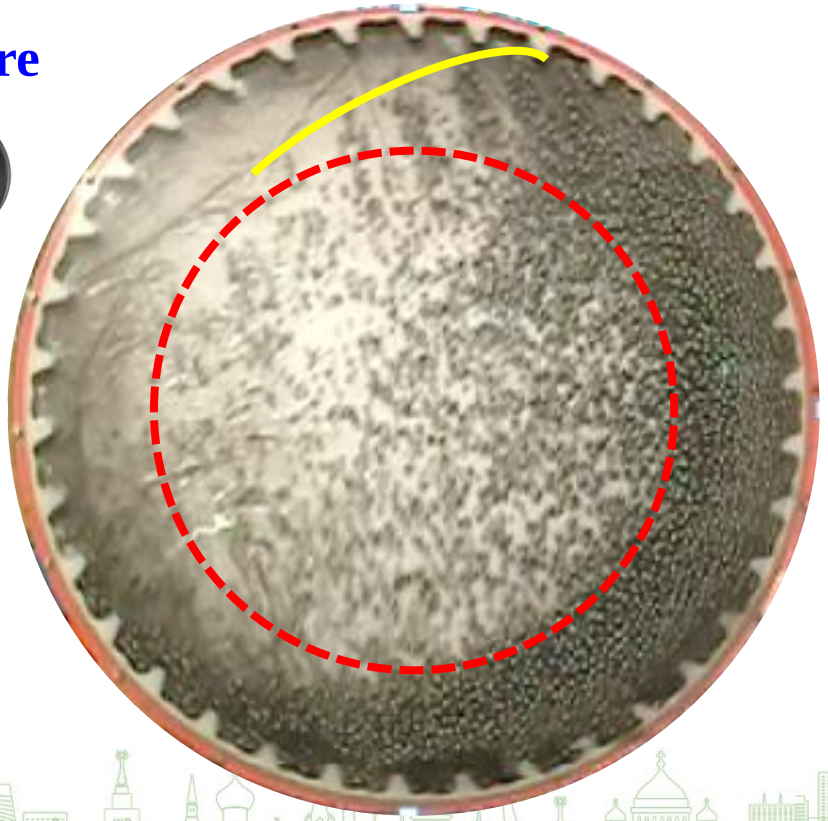
Ore



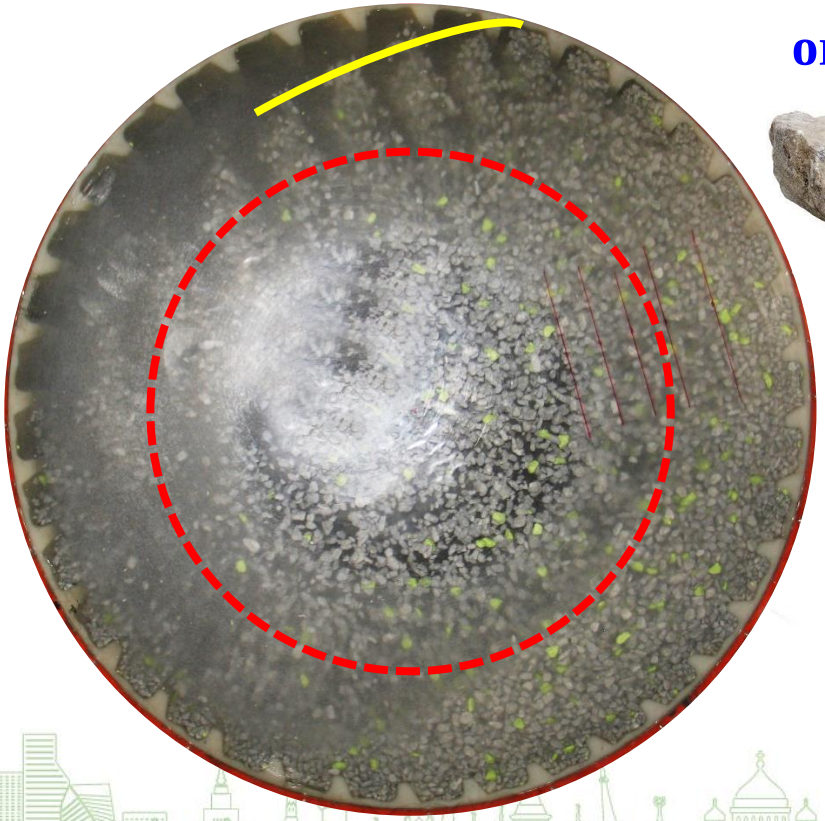
85% of critical speed; 25% filling

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