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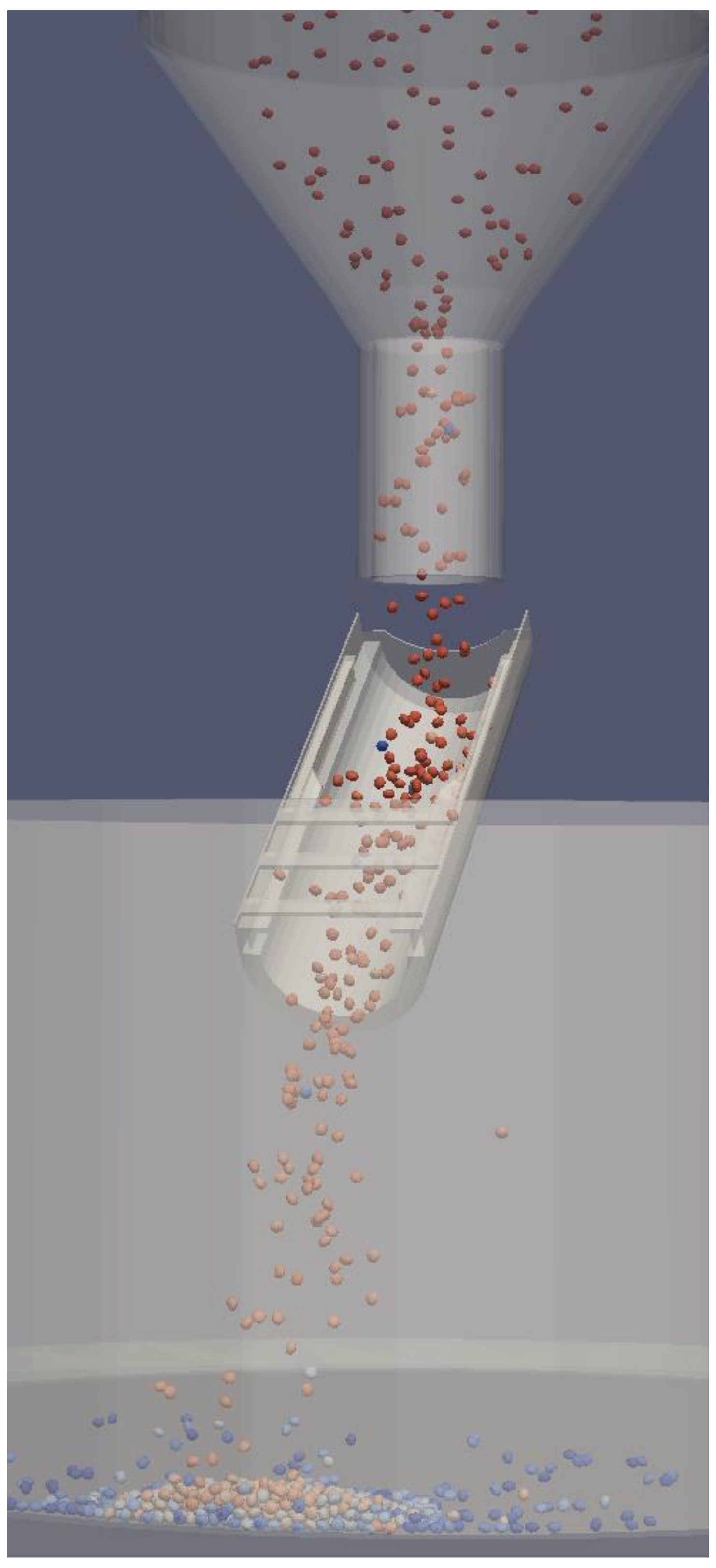
Application of Non-Spherical Discrete Element Methods to the Blast Furnace

The project aims to create a validated non-spherical Discrete Element Method (DEM) model of the blast furnace (BF) so that we can investigate the effect particle shape has in the charging process.

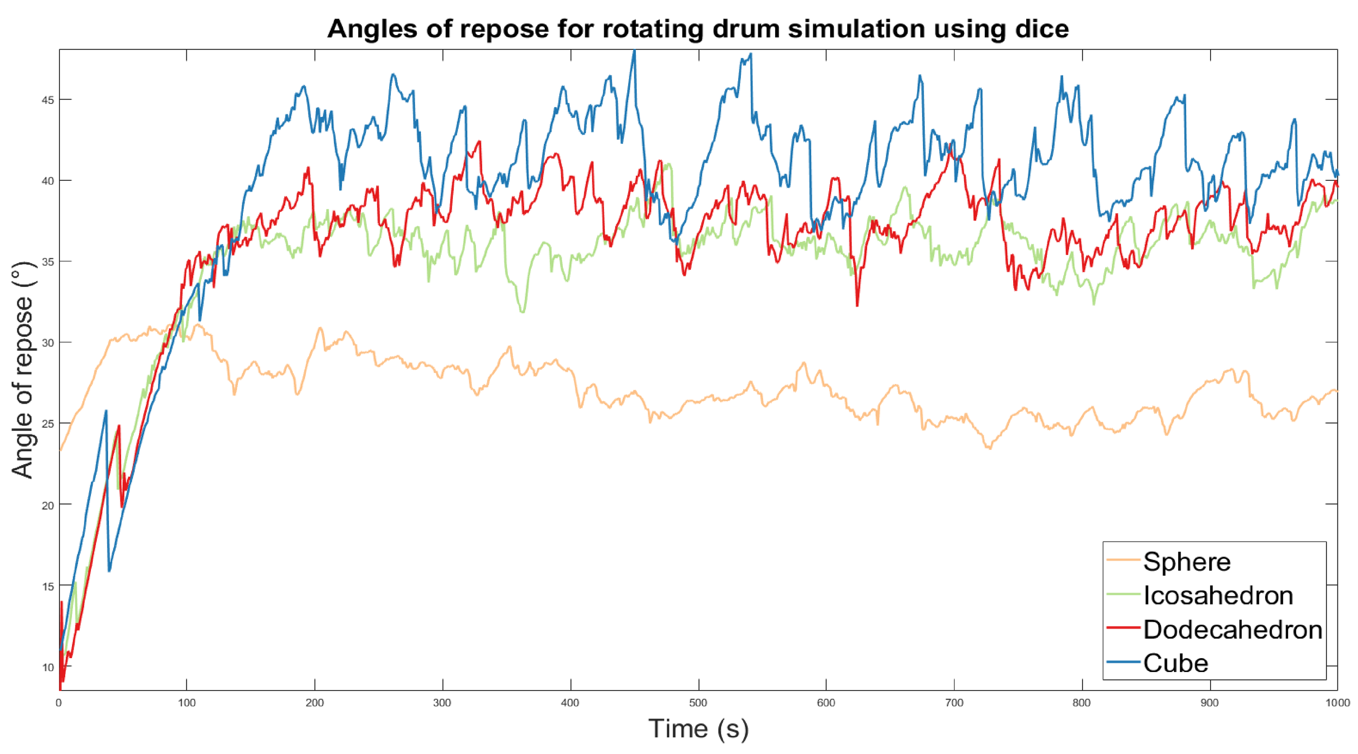
The BFs can account for 90% of the CO_2 emissions and 70% of the energy consumption of the steel making process (including the processing of the burden material) [1].

The furnace performance and flow distribution are dependent on the distribution of the burden material. In order to control this distribution, we need to accurately predict the charging of particles on the top layer of the BF.

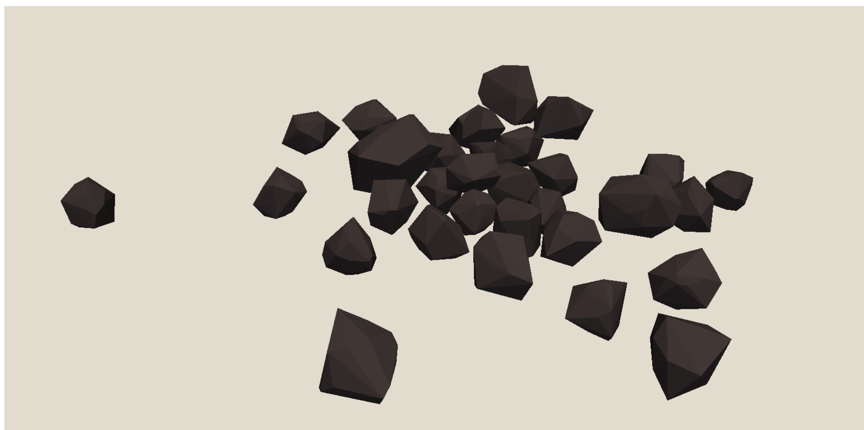


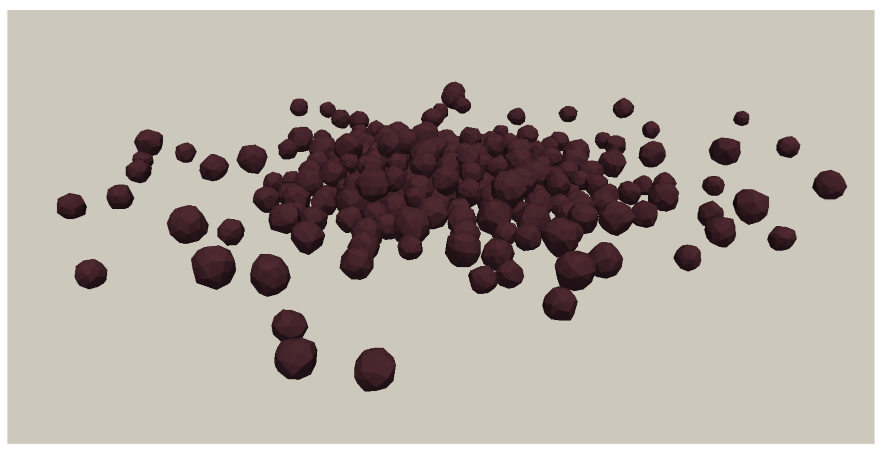
The Discrete Element Method

DEM deals with the motion and effect of large systems of particles, it is a numerical method used to understand and predict the behaviour of granular materials. The particle's trajectories are computed by evaluating any contacts between the particles and using Newton's equations of motion. DEM models can be differentiated from Molecular Dynamics by the inclusion of contact deformation, rotational degrees of freedom, and friction.



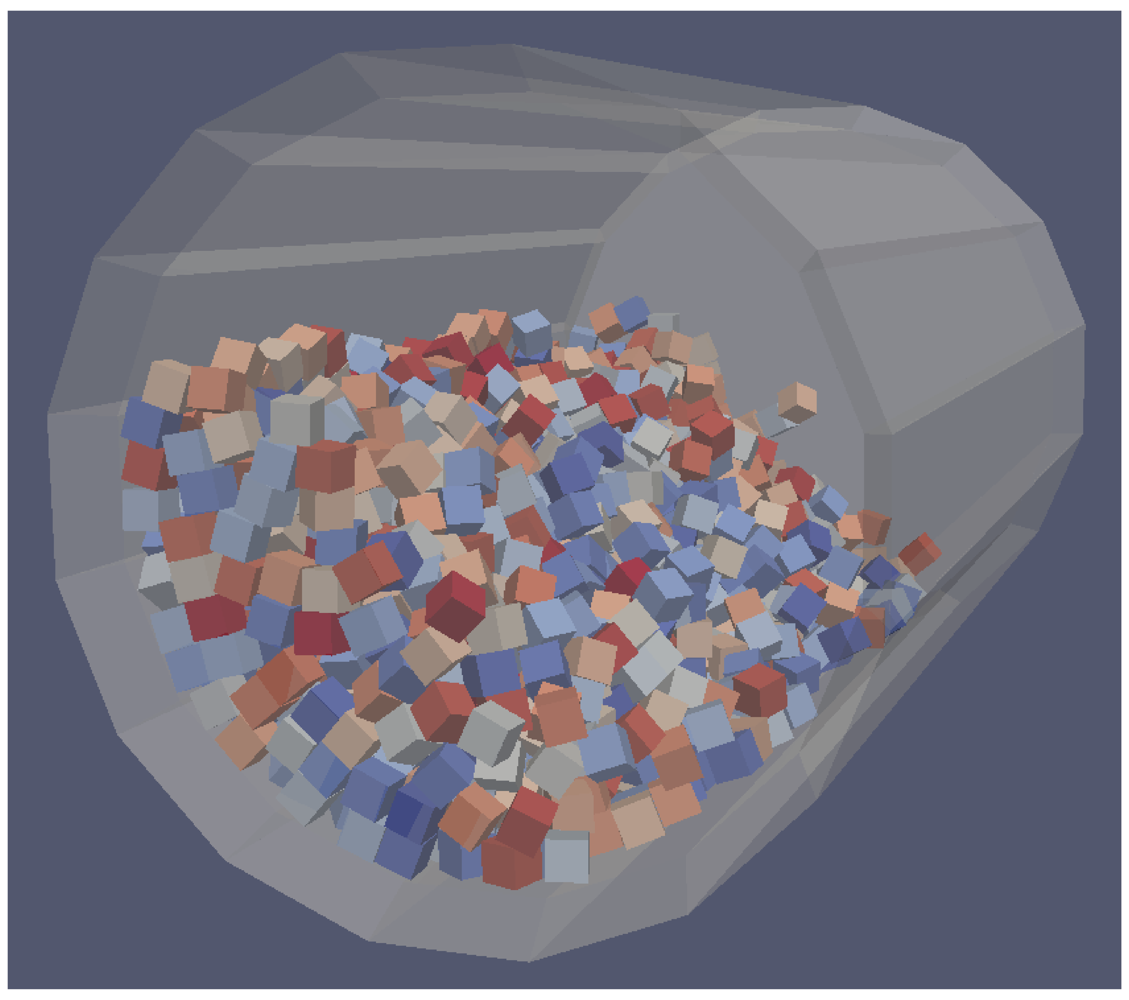
Angle of Repose (°)	Sphere		Icosahedron		Dodecahedron		Cube		Error
Experiment	27.19		36.52		37.30		42.06		n/a
[3]	25.41	-1.78	37.79	+1.27	37.96	+0.66	44.58	+2.52	±1.58
In-house	26.82	-0.37	36.29	-0.23	37.81	+0.51	41.70	-0.36	±0.37

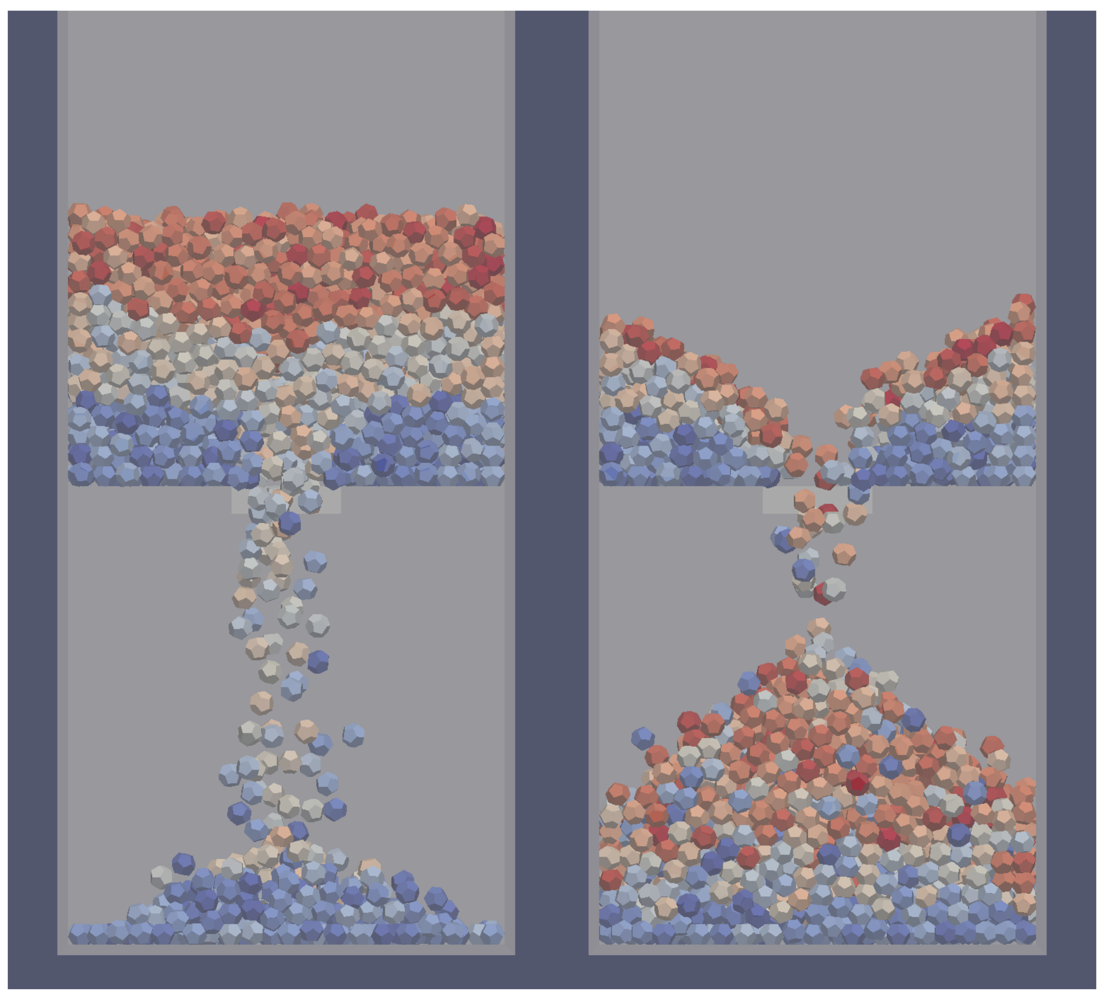




Model Validation

A polyhedral particle DEM model has been written in FORTRAN and validation has begun. We have repeated rotating drum and hopper discharge experiments found in academic journals [2],[3]. The angles of repose given by our drum simulations are in good agreement with the experimental results. We are currently investigating how rolling and twisting friction can affect these simulations.





However, our hopper simulations do not agree with the results found. The flow of particles is slower than observed and less material is left in the hopper. We believe this is due to problems with the static friction.

Once we have solved the issues with the static friction we can begin creating our own tests so that we can validate the model against the burden material of the blast furnace. This will be done using slump, rotating drum, hopper discharge tests, before moving on to industrial scale validation.

Once the model has been validated we will then begin optimisation and parallelisation. The scalability of the method will be addressed, so we can put our simulations on a cluster. We hope to get a full blast furnace simulation running within the next two months.

[1] U. Sydney, S. Kuang, Ã. Z. Li, and A. Y. Ã, "Review on modelling and simulation of blast furnace Review on Modelling and Simulation of Blast Furnace", *Steel Research Int.,* 2017.

[2] D. Höhner, S. Wirtz, and V. Scherer, "Experimental and numerical investigation on the influence of particle shape and shape approximation on hopper discharge using the discrete element method," *Powder Technol.*, 2013.

[3] D. Höhner, S. Wirtz, and V. Scherer, "A study on the influence of particle shape and shape approximation on particle mechanics in a rotating drum using the discrete element method," *Powder Technol.*, vol. 253, pp. 256–265, 2014.

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