Summary

Nemag is a supplier of grabs for dry bulk handling companies and is looking for ways to improve the performance of their grabs. Discrete Element Method, DEM, simulations can help reduce the cost of design through replacing expensive physical prototypes and testing with virtual ones. The iron ores focussed upon in this research are Sinter Feed Carajas, Sinter Feed Guaiba (SSFG), and Sishen. All three materials are transported in a wet sate with the moisture content varying between different parts of the material in the ship's hold. This is important for the design of grabs as the moisture content is known to have an effect on the bulk density and angle of repose of iron ores. However, this effect has not been quantified for either material, so the focus of this research was on understanding the effect and providing results for future DEM calibration.

Three experiments were carried out: one bulk density experiment and two angle of repose experiments using different methods (ledge and free cone). The bulk density was found at four levels of compaction: completely loose, vibrated, compressed, and compressed while vibrated. Each experiment was carried out at a number of moisture contents between dry and liquidation.

The bulk density experiments showed that with increasing moisture content the bulk density of the iron ores decreased to a minimum before increasing again. This is similar to previous research.[1] The experiments identified that the type of ore tested will affect the point at which this minimum occurs. It was also noted that the minimum bulk density occurred at a lower moisture content when the sample was vibrated which has not be found before.

Table 1 Minimum and maximum bulk densities

Ore type	Minimum			Maximum		
	Bulk density, kg m^{-3}	Moisture content, %	Condition	Bulk density, kg m^{-3}	Moisture content, %	Condition
Carajas	2023 ± 30	6.92 ± 0.20	Loose	3351 ± 13	10.76 ± 0.30	Compacted & vibrated
SSFG	2077 ± 36	5.09 ± 0.24	Loose	3421 ± 13	8.93 ± 0.34%	Compacted & vibrated
Sishen	2229 ± 8	2.68 ± 0.1	Loose	2824 ± 17	0.05 ± 0.01	Compacted & vibrated

The angle of repose did not show a significant dependence on moisture content. After a small rise in the angle of repose, as the moisture contents of the materials were first raised from dry, the SSFG stayed at between 63 and 64 degrees and the Carajas between 62 and 63 degrees on the ledge method. Only three measurements were taken for Sishen before the material stopped holding liquid and they were 47.6 degrees, 45.6 degrees and 54.8 degrees for moisture contents of 0%, 1% and 3% respectively. There was a big jump in the angle of repose just before liquidation for all the materials: Carajas jumped to 83.6 degrees, SSFG to 83.1 degrees, and Sishen to 54.8 degrees. There was also a substantial but steady difference in measurements between the two angle of repose rigs which is probably down to a combination of wall effects and compaction occurring in the ledge method, and

a too small free cone. This means that the true angle of repose is difficult to decide but the trend is still representative of the effect of moisture content.

Future research could go in two directions from this study. One direction is that the results found here should be used to calibrate DEM simulations. However, future research should also focus on extending this study to more iron ores with different properties so that the properties that control the effect of moisture can be found e.g. what properties determine the moisture content at which the density is minimised. Finally, the wall effects on iron ore at different moisture contents should be investigated as this would be useful for experimental work and for DEM simulations.