EFFECT OF RAW MATERIAL PROPERTIES ON THE KINETICS OF IRON ORES GRANULATION

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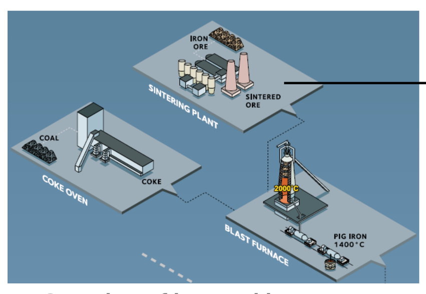
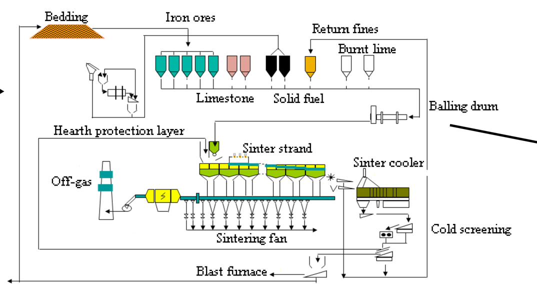
Introduction

In modern ironmaking, granulation is the first step of the sintering process. It is typically carried out in continuous drum granulators using water as a binder, and involves multiple components besides iron ores, such as solid fuel and fluxes (limestone, lime), return fines and other recycled materials.



Overview of iron making process



Process flow diagram of sinter plant

Drum granulator used in iron making industry

As it is necessary to maintain a consistent quality of the granules (size distribution, porosity, strength, etc.) despite of the varying iron ore origins, the question arises as to how the properties of the iron ore particles influence the granulation process.

Materials & Methods

This study focuses on the iron ores granulation process in a laboratory-scale batch drum granulator using water as a binder and on the investigation of the influence of raw materials properties (morphology and wettability of the primary particles) on its kinetics. Laboratory experiments were carried out in a stainless steel batch granulation drum 8.5 cm in diameter and 4.25 cm long.

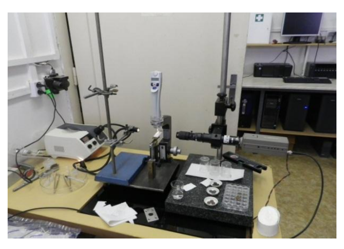
TURBULA® Shaker-Mixer

Drum granulator

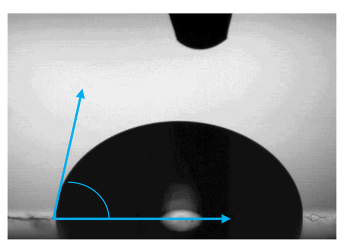
A comparison of the granulation behaviour of three commercial iron ores (magnetite, hematite and goethite) has been carried out. The wettability of the powders has been characterised by contact angle measurement.

Manual hydraulic press CARVER SPEX

Pellets of iron ores powders



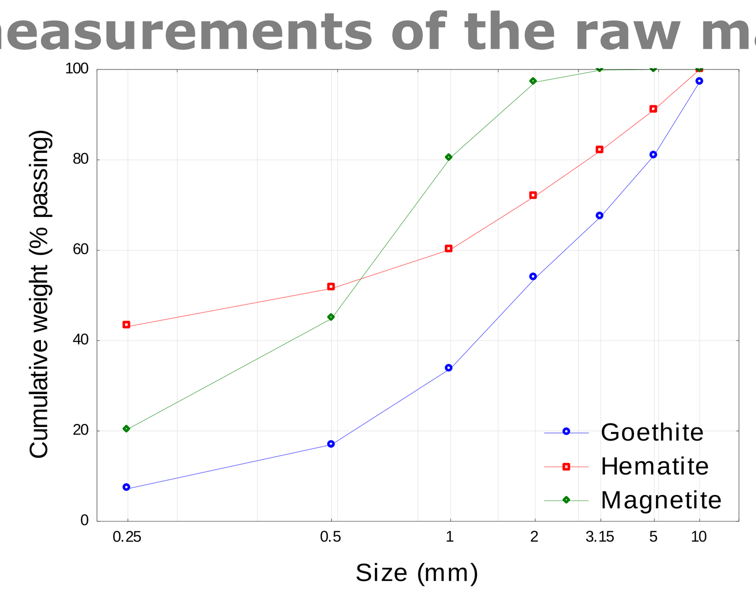
Contact angle goniometer

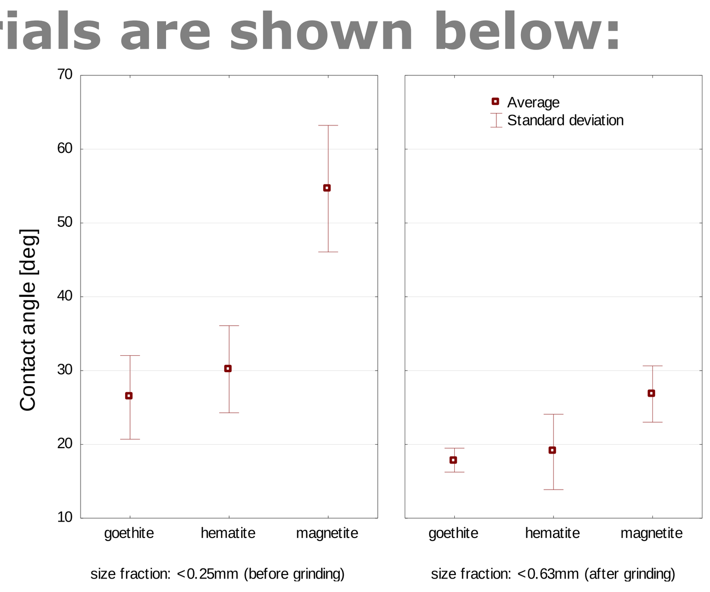


Measurement of contact angle

Preliminary results and future work

The cumulative size distribution and contact angle measurements of the raw materials are shown below:





The principal mechanism in the granulation process is the layering of fine particles onto larger nuclei particles [1]. The sieve sizes specifically selected were the fractions 1-2 mm and <0.25 mm. The fraction 1-2 mm represents the part of iron ore that act as nuclei in our drum granulation experiments. The chemical analysis of raw materials are:

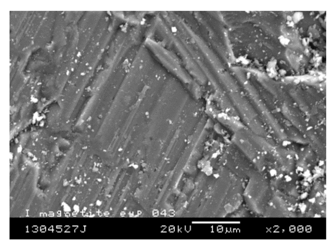
Components (% mass)	Fe tot	Fe^{2+}	CaO	SiO_2	MgO	Al_2O_3	P	Mn	C tot.	S tot.	LOI *
Goethite	56.30	0.28	0.20	6.32	0.20	2.87	0.1	0.08	0.39	0.014	10.42
Hematite	64.51	0.04	0.013	4.23	0.009	0.9	NA	NA	0.058	0.003	-2.14
Magnetite	70.35	21.95	0.29	0.88	0.40	0.31	0.04	0.04	0.034	0.018	<0.01

*LOI: Loss of ignition

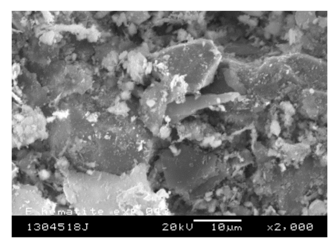
The skeletal density of iron ores was determined by a helium pycnometer, the specific surface area was determined by BET and the voidage by mercury porosimetry. The results are summarized in the following table:

Iron ore	Granulometry	Skeletal Density (g/cm^3)	Specific surface (m^2/g)	Pore volume (cm^3/g)
Magnetite	1-2 mm	5.117	0.016	0.00125
	<0.25mm	5.131	0.18	-
Hematite	1-2 mm	4.766	3.4	0.035
	<0.25mm	4.837	1.7	-
Goethite	1-2 mm	3.857	20.4	0.07
	<0.25mm	3.853	22.1	-

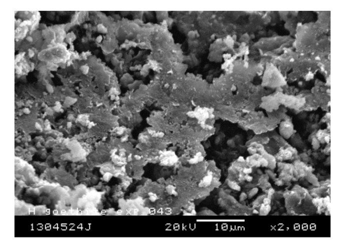
The binder-solid ratio is different for each iron ore because of the various porosities (higher for goethite and lower for magnetite [2]). The surface morphologies of the three iron ores taken with SEM are presented below.



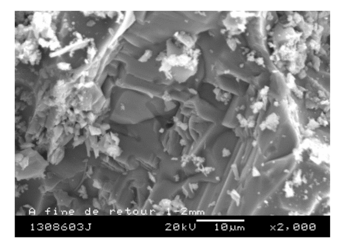
Magnetite



Hematite



Goethite



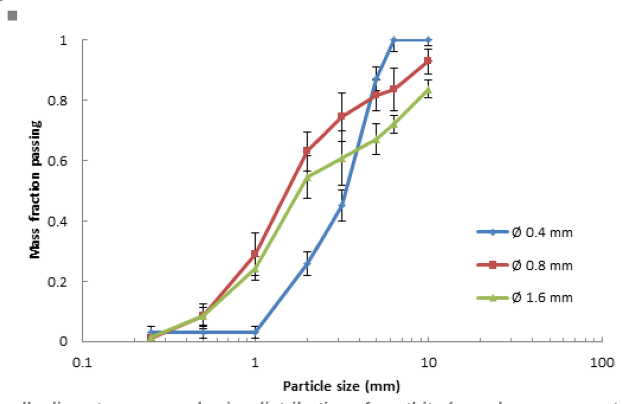
Return fines

A series of experiments was carried out for each iron ore in order to determine the impact of nuclei ratio, binder content and residence time. Water spatial and temporal distribution inside granulation drum is crucial for a good control of the results and for a good granulation. The firsts experimental granulation trials showed that the granule size distribution is very sensitive to the needle diameter.

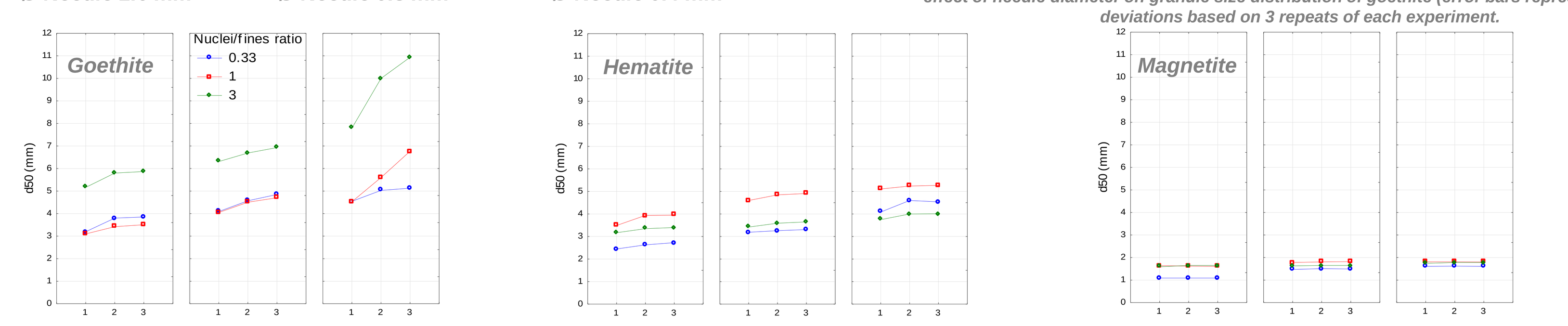
Ø Needle 1.6 mm

Ø Needle 0.8 mm

Ø Needle 0.4 mm



effect of needle diameter on granule size distribution of goethite (error bars represent standard deviations based on 3 repeats of each experiment.

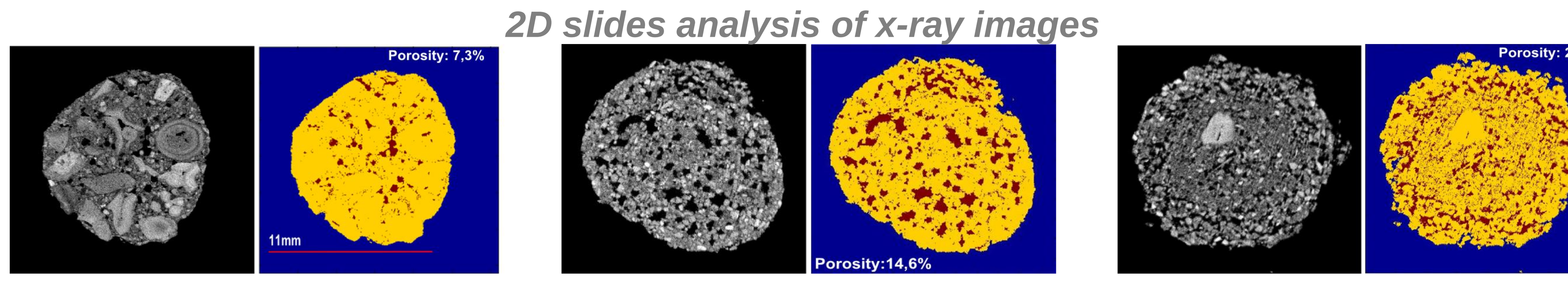


Plot of d50 versus time (first horizontal axe in minutes) for different binder-solid ratios (second horizontal axe) and nuclei-fines ratios (blue, red and green lines) in granulation experiments

Ongoing investigation in the laboratory drum granulator aims in particular to establish the influence of porosity on granules strengths. X-ray µCT and x-ray image analysis have been used to estimate granules characteristics like porosity. These trials, using binary mixtures, allow to better focus the next steps of this work via the use of multispectral imaging of iron ores minerals and shape analysis [3].

A model of granule microstructure formation applicable to layering growth in low-shear wet granulation processes will also be used and improved within this research [4].

2D slides analysis of x-ray images



Raw image | Thresholding | Raw image | Thresholding | Raw image | Thresholding

Literature

[1] Litster et al. Kinetics of iron ore sinter feed granulation, Powder Technology, 62 (1990) 125-134.

[2] Iveson et al. Liquid penetration rate into submerged porous particles: theory, experimental validation and implications for iron ore granulation and sintering, Mineral Processing and Extractive Metallurgy, 110 (2001) 133-14.

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[4] Š. František. Sub-granule scale modelling, in: A.D. Salman, M. J. Hounslow, J. P. K. Seville(Eds.) Handbook of Powder Technology, Elsevier Sci. B.V., 2007, pp. 1353-1377.

Acknowledgements

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