FFG

K1-MET

Competence Center for Excellent Technologies in Advanced Metallurgical and Environmental Process Development

Main location	Linz, Upper Austria
Other locations	Leoben, Styria
Thematic field	K1-MET has its focus on the modeling and simulation of metallurgical processes, including metallurgical raw materials and refractories with the goal of an optimal process control with respect to product quality, zero waste and the minimization of energy and raw materials.

Success story summary

Characterization of the reducibility / disintegration of lumpy iron carriers (Area IV, Project 4.2)

Within this research work different kinds of raw materials have been investigated for their behavior and applicability in different reduction aggregates of various ironmaking routes. The objective of this work is to explore a correlation between the morphological and mineral composition of the different raw materials and their behaviour during processing (reducibility, mechanical strength, metallic iron formation, etc.). Additionally the influence of alkalis is investigated.

Success story

Introduction:

Due to the rising importance of the economical and environmental aspects of ironmaking, one major focus in research activities is the continuous improvement and optimization of prevailing and approved processes. For an optimized operation mode of blast furnace, direct and smelting reduction processes respectively the reduction performance as a result of the raw material properties is an important factor. Within this investigation lumpy iron carriers namely lump ores, pellets and sinters as feed material are investigated for their mineralogical and microstructural composition, their capability of oxygen release, their mechanical strength and the ability to retain these strength during processing. Furthermore process related influencing factors of the materials performance like different gas components, temperatures and alkalis are investigated.

For all raw materials provided from the industrial partners the testing procedures can be summarized as follows:

- Morphological characterization of the material prior and after the reduction process by light microscopic means
- Reducibility testing according to standardized testing procedures and according to industrial scale process conditions
- Testing of the mechanical behaviour prior and after reduction in a rotating tumbling drum

The research work started with testing different lump iron ores of different morphological types. Within the second workpackage different industrial scale fabricated pellet grades have been investigated and the last step is the investigation of sinter samples produced both in industrial scale and lab scale facilities.

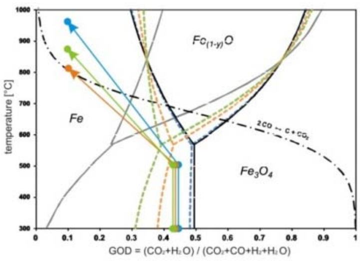
Consequently with a better understanding of the coherency of raw material characteristics and behaviour under industrial scale ironmaking conditions a more selective and purposive assortment of lumpy iron carriers for optimization of existing processes in terms of both, economical and environmental aspects should be realized.

Correlation between reduction rate and mechanical properties at industrial scale process conditions:

For assessing the materials properties under industrial scale process conditions, the following considerations were taken into account. When the material is charged to the shaft part of any industrial scale aggregate, the top gas is not particularly hot and has a low reduction potential. During the decent of the material the temperature is rising and the gas reduction potential is getting stronger. For the different types of reduction aggregates these consideration have been applied and led to three different testing conditions, reflecting the process conditions for the indirect reduction in a blast furnace (without and with 3% and 6% H_2 respectively) and direct reduction shaft furnaces of the MIDREX® and COREX®. Figure 1 shows these time dependent temperature and gas profiles in the Baur-Glaessner diagram. On the right hand side the reduction progress for a hematitic ore during the test is given (solid lines) as well as the reduction rates (dashed lines) which refer to the first derivation of the reduction degree. The table gives the characteristic values R¬80 (time to gain 80% of reduction) and DT+6.3 (percentage of material > 6.3 mm after tumbling). The following main conclusions can be draw out of the test for all materials:

- The presence of hydrogen enhances the reduction progress. Though the final reduction temperature for direct reduction shaft conditions are lower the reduction proceeds faster due to the increased H2 content (25% for COREX and 54% for MIDREX). This effect was also occurring by testing pellets and sinters, however the accelerating effect was less noticeable.
- With the increase of reduction rate the mechanical properties are getting worse. Especially the difference between testing conditions at high temperatures and low H2 (BF-conditions) and lower temperatures and high H2 conditions (DR) are distinct.

	BF			DR	
	0% H_2	3% H_2	6% H_2	COREX	MIDREX
R_{80} [min]	250	222	200	140	123
$DT_{+6.3}$ [%]	87.8	88.0	83.5	77.3	73.4



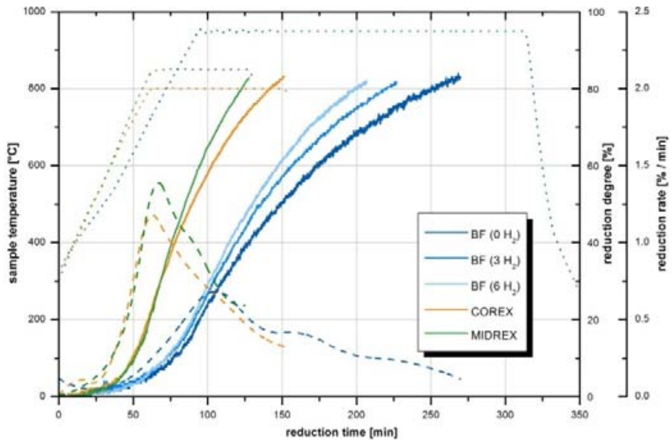


Figure 1: Process related process conditions (upper left side), reduction progress (right) and characteristic values (downer left)

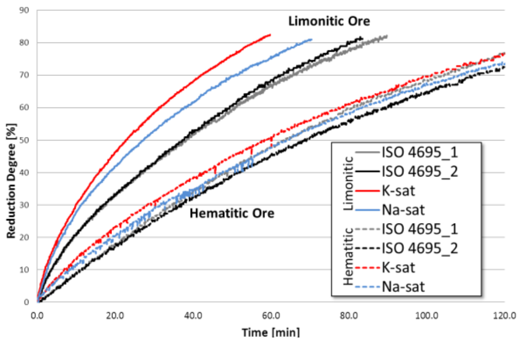


Figure 2: Influence of alkali-addition to reducibility and reduction velocity

Influence of alkalis on the reduction behavior:

For these tests different iron ores (limonitic and hematitic) have been saturated in a solution of potassium or sodium and compared to the testing results of the ISO 4695 tests with non-saturated ores. It could be seen that:

- Porous iron ores like limonite show a higher admission of alkalis during saturation. Also the microprobe detected higher alkaline-contents in porous phases.
- The addition of alkalis led to higher reduction velocities in limonitic ores, yet hematitic ores were not significantly affected.
- All saturated materials showed sticking behaviour during the reduction tests. The disintegration was not significant in former hematitic ores, but the emission of fines in former limonitic ores doubled.

Structural evolution during reduction and different forms of metallic iron:

As an example of the morphological investigation prior and after the reduction and the dependence of the metallic iron formation on the raw material micro structure, Figure 3 shows light microscopic pictures of different ore types. The left side shows the inward moving layers of Femet – FeO – Fe3O4 – Fe2O3 during the reduction process. The right pictures make the distinct differences of the formed metallic iron obvious. Dense and coarse grained structures will lead to a slow reduction rate and layer-like metallic iron shells whereas fine grained and porous structures lead to fine distributed iron scraps.

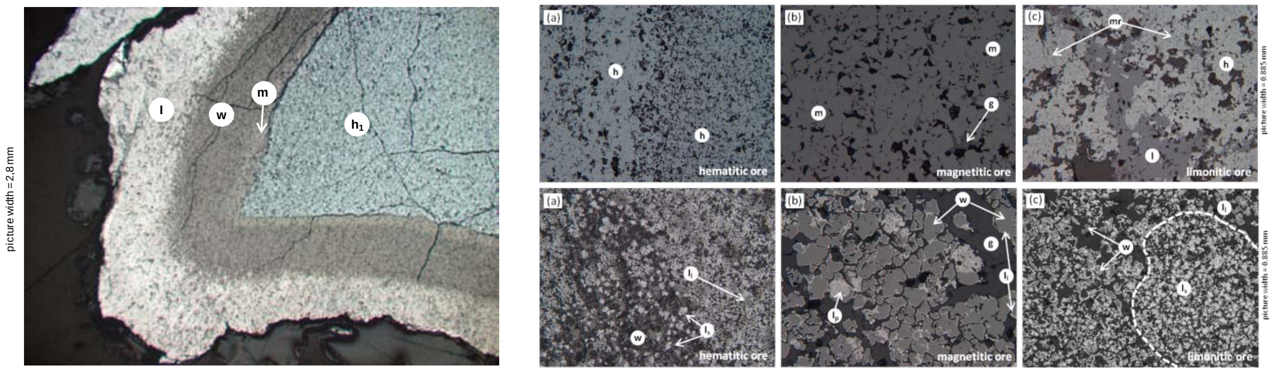


Figure 3: Reduction progress curves of different pellet grades (left) and light microscopic pictures of selected regions of pellets (right)

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Impact and effects

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Contact:	Chair of Metallurgy, Montanuniversitaet Leoben, eisen@unileoben.ac.at +43 3842 402 2201, http://www.metallurgy.ac.at +43 3842 402 2201, http://www.metallurgy.ac.at