Estimation tool for BF burden softening

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Introduction

Ferrous burden loses its permeability in the cohesive zone of a Blast Furnace (BF) due to softening and melting. Thus, the formation of the cohesive zone has a significant effect on the efficiency of gaseous reduction in the BF shaft which affects the efficiency of the whole BF process. There are various ferrous BF burden materials with different chemical compositions and softening properties. The ferrous burden softening and melting properties determine the formation of the cohesive zone in the BF process which makes them important metallurgical properties. The developed estimation tool for BF burden softening can be used to estimate the softening temperatures of different ferrous burden materials and also to find optimal burden compositions.

Research methods

The developed tool is based on number of laboratory trials and thermodynamic calculations made with FactSage software (versions 6.4 and 7.0) and its oxide database (FToxid).

Experimental devices

Laboratory scale Cohesive Zone Simulator (CZS, Fig. 1) and industrial Advanced Reduction Under Load (ARUL) test were used in the tool development. They are custom-made furnaces with gas and temperature controls, mass balances and sample shrinkage and pressure drop measurements. Detailed descriptions of the experimental devices are presented in the literature, respectively. (1,2)

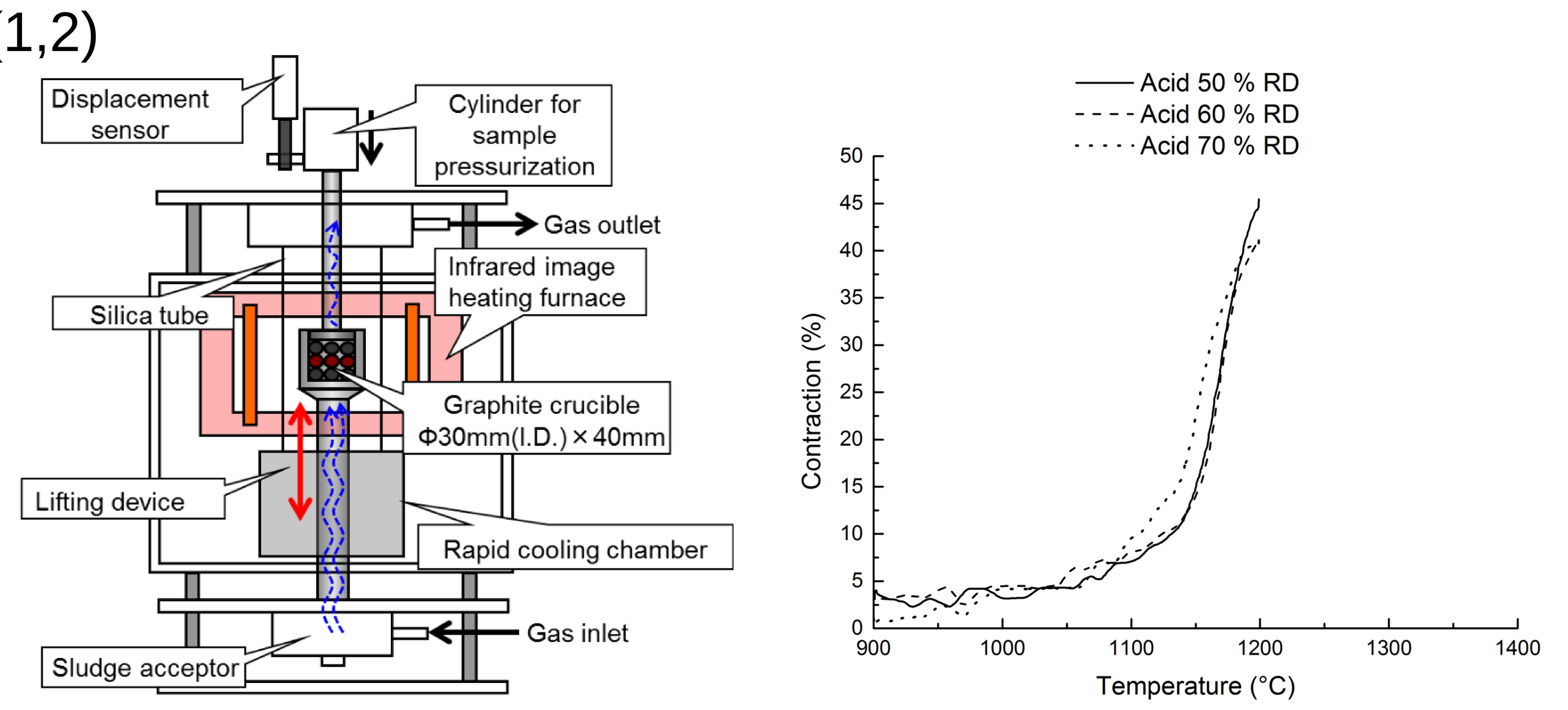

Figure 1. Illustration of cohesive zone simulator (left) and shrinking curve of acid iron pellet during heating and compression (right). (1)

Analytical methods

Optical and electronic microscopes were used as analytical methods in the tool development. In Fig. 2 are shown optical microscope images from the core region of hard (left) and soft (right) olivine fluxed iron pellet. The phase compositions were determined by SEM-EDS method.

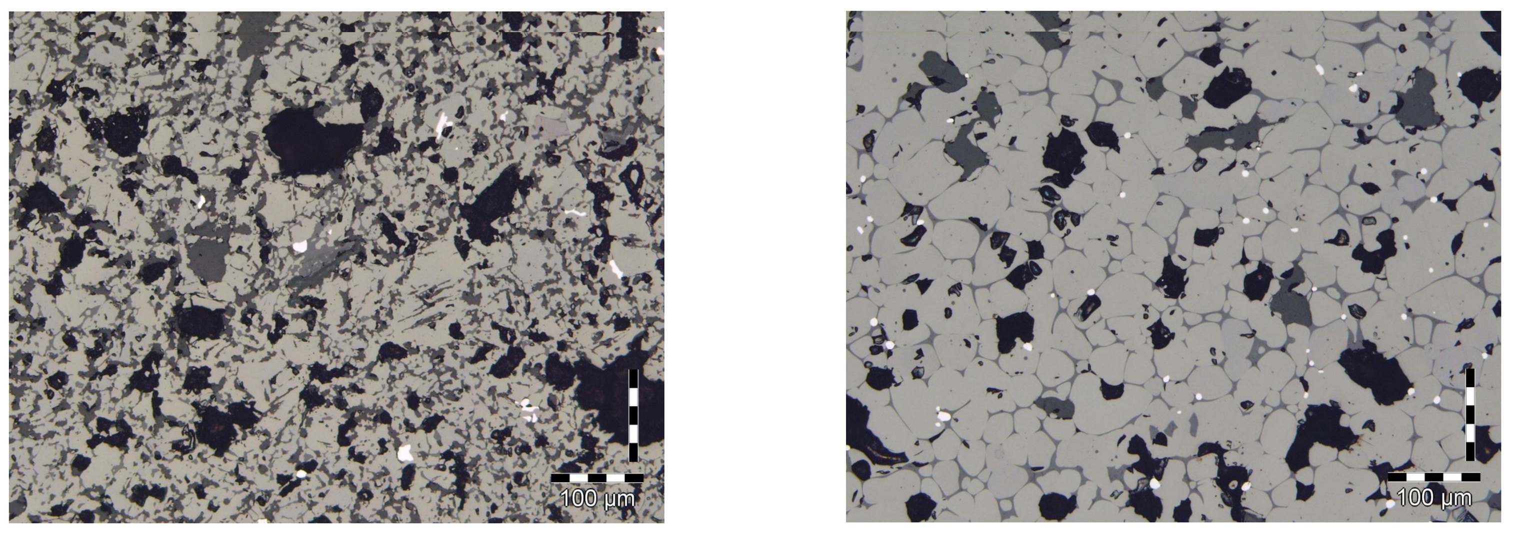

Figure 2. Optical microscope images from the core region of hard (left) and soft (right) olivine fluxed iron ore pellets.

Thermodynamic calculations

The FeO-SiO_2-CaO-MgO-Al_2O_3 system of the burden material is used as an input value for the tool with assumptions of the state of the burden in the conditions of the BF cohesive zone. With the tool the solidus and liquidus temperatures can be calculated and the amount of liquid oxide phase fraction can be estimated. Components of SiO_2, MgO, CaO, Al_2O_3 and Fe_{tot} are considered in the calculations. With the Phase Diagram module in FactSage phase diagrams for the 5-component FeO-SiO_2-CaO-MgO-Al_2O_3 systems with constant CaO, MgO and Al_2O_3 contents can be calculated as shown in Fig. 3. Three types of solution phases are considered in the FactSage calculations: a liquid oxide phase (FToxid-SLAG), a solid monoxide phase (FToxid-MeO) and a solid olivine-type phase (FToxid-Oliv). Additionally, numerous relevant pure invariant solid phases are taken into account. Reduction conditions can be taken into account in the calculations considering the partial pressure of oxygen. (3)

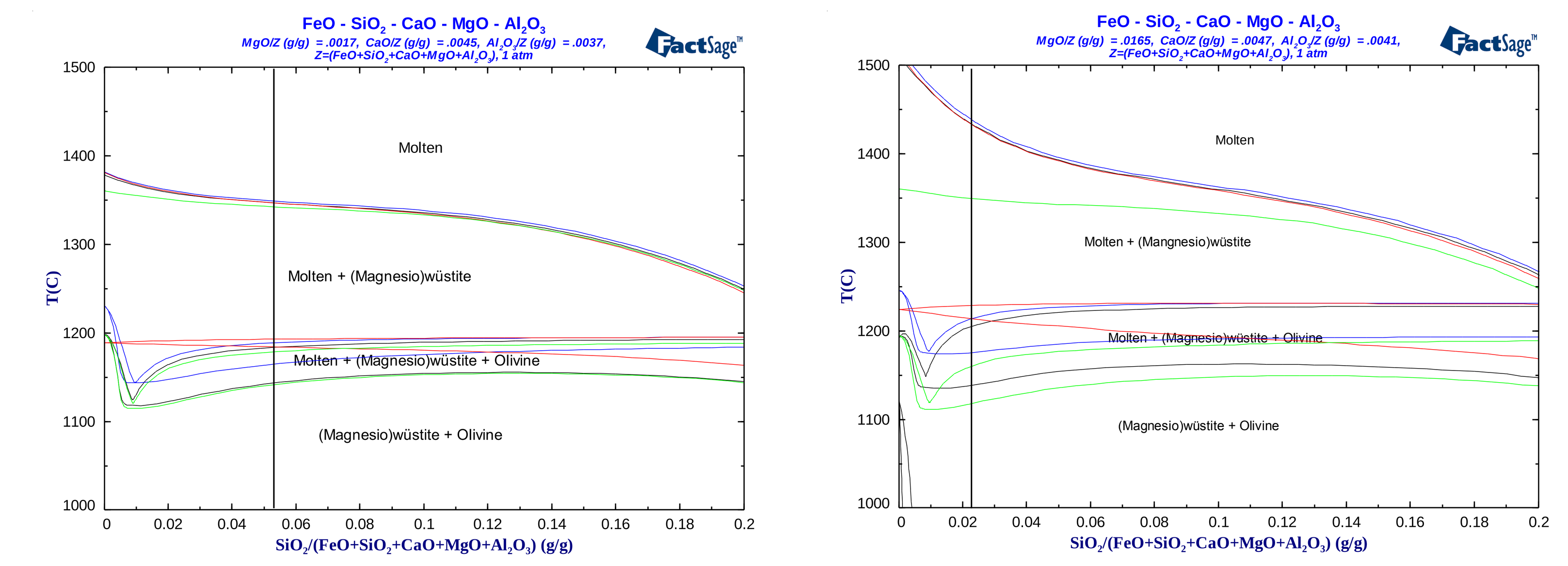

Figure 3. Phase diagrams for FeO-SiO_2-CaO-MgO-Al_2O_3-system illustrating the melting behavior of acid (left) and olivine (right) pellets: Black lines = All five components included in the system. Blue lines = Al_2O_3 excluded. Red lines = CaO excluded. Green lines = MgO excluded. (3)

Benefits

Optimal selection of burden materials with desired softening and melting properties leads to higher efficiency in the BF process, savings in coke consumption and reduction in CO_2 emission.

References

(1) Kemppainen, A., Ohno, K.I., Iljana, M., Mattila, O., Paananen, T., Heikkinen, E.P., Maeda, T., Kunitomo, K., Fabritius, T., 2015. Softening behaviors of acid and olivine fluxed iron ore pellets in the cohesive zone of a blast furnace. ISIJ Int. 55 (10), 2039–2046.

(2) Iljana M., Kemppainen, A., Paananen, T., Mattila, O., Heikkinen E-P., Fabritius, T. Evaluating the Reduction-Softening Behaviour of Blast Furnace Burden with an Advanced Test. ISIJ International (2016). ISIJ Int. 56 (10), 1705-1714.

(3) Heikkinen, E.-P., Kemppainen, A., Iljana, M., Mattila, O., Paananen, T., Ohno, K-I., Kunitomo, K., Maeda, T. and Fabritius, T. "Estimation of softening behavior of BF burden materials using computational phase diagrams for multicomponent systems", CALPHAD XLV, 29th May - 3rd June 2016, Awaji Yumebutai, Japan.

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