High Temperature Microscopy Laboratory: The Kinetics of Alumina Dissolution in Slag

Location: Live streamed

SAFETY

As the lab will be live streamed no safety personal protective equipment is required.

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Aims:

- To familiarise the students with the use of advanced experimental equipment in the collection of scientific data and the use of such data in metallurgical processing.
- To measure the dissolution rate of alumina in slag.

Additional PPE:

No additional PPE is required.

Laboratory:

Students will observe the dissolution of alumina particles at different temperatures in a steel making slag using the high temperature confocal microscope (HTCM). The data HTCM are recorded in a video format. These videos will then be analysed to obtain approximately 20 measurements of the changing alumina particles radius as it dissolves in the slag. The resulting radius versus time data will then be analysed using current theory to determine the mechanism of dissolution (mass transfer or chemical reaction control).

Background Theory:

The shrinkage core model (SCM) has been used to successfully represent the inclusion dissolution process in slags[1,2]. This model assumes first order kinetics. Full details of the derivation and the applicability of this model can be found in Levinspiel[3]. Using the SCM model it can be shown that for chemical reaction control at the particle slag interface and mass transfer control in the slag phase in the stokes regime can be represented by equations 1 and 2,

$$\left(\frac{R}{R_O}\right)-1=\frac{bk_R(-\Delta C)}{R_O\rho_{particle}}t \qquad (1)$$

$$\left(\frac{R}{R_O}\right)^2-1=\frac{b2D(-\Delta C)}{R_O^2\rho_{particle}}t \qquad (2)$$

where R is the radius, R_O is the radius at time zero, k_R is a chemical reaction rate constant, D is the diffusion coefficient of the rate limiting species in the slag, $\rho_{particle}$ is the density of the dissolving particle, t is time, b is the stoichiometric coefficient of equation 1 and equals 1. The ΔC term is the thermodynamic driving force for reaction in molar units. It may be represented by the difference in molar concentration between the slag bulk and the particle-slag interface of the rate limiting species.

For simplicity of analysis and presentation A and B (given equations 3 and 4) will define the radius ratio terms of the left hand side of equations 1 and 2 for chemical reaction control and mass transfer control respectively.

$$A=\left(\frac{R}{R_O}\right)-1 \qquad (3)$$

$$B = \left(\frac{R}{R_O} \right)^2 - 1 \qquad (4)$$

From these equations it can be seen that plots of A versus time for chemical reaction control or B versus time for mass transfer control should be linear and pass through the origin if the respective mechanism is rate controlling.

Report: Part 1 (3 pages maximum)
Produce a word processed report containing all relevant information and results using a standard structure for a laboratory report. Keep any preamble or background statement to a minimum. Ensure you have a description of your experimental method, melting procedure used, stated **key calibration data for conversion of pixels (or other image reference) to standard SI units** and have noted the temperature and slag composition used in your experiments.

Report: Part 2 (2 page maximum)
Solid non-metallic particles must be removed from a liquid metal prior to solidification or they negatively affect the solidified metals physical properties. Explain how your laboratory measurements and laboratory measurement approach can be used to optimise the non-metallic particle removal from the melt. Key aspects to consider will be

i. Particle type
ii. Particle size
iii. Reaction mechanism
iv. Slag composition

Use appropriate fundamental relations/equations, phase diagrams and mechanistic schematics to answer this question.

Assessment: 70% of the marks will relate to details of the experimental technique and results reported. The other 30% will relate to the discussion in part 2.

Report Layout:
It should be in a word processed format, 10 or 12 point typeface and no more than five A4 pages long (3 pages part 1 and 2 pages part 2) including any graphics, tables and references and have a margins of 10 mm or greater. Failure to adhere to the report layout will result in a 10% (3 out of 30) penalty for the assignment.

Submission Guidelines
The report is due by 1/10/2020 and is to be e-mailed to monaghan@uow.edu.au.

References (are available in the library and moodle)

[1] Monaghan, B.J., Chen, L. and Sorbe, J.: Ironmaking Steelmaking, Vol. 32, 2005, pp258-264.
[2] Monaghan, B.J. and Chen, L: Ironmaking and Steelmaking, Vol. 33, 2006, pp323-330
[3] Levenspiel, O: The Chemical Reactor Omnibook; 1989, Oregon, USA, OSU Book Stores Inc., pp51.1-51.6 (available on Moodle under MATE305).