Reactive gas injection in metallurgy: where's the limit?

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Reactions between gas and liquids or solids are common in metallurgy, and gas injection has become an established way to increase the process intensity. The principle is often an integral part of bath smelting concepts, with examples such as convertors (LD or Pierce-Smith), TSL furnaces, QSL, SKS, submerged plasma… By increasing injection speed, gas volume, or number of nozzles, or changing the gas composition, existing processes can be further intensified. Another goal can be to increase the efficiency of the reaction, e.g. the percentage of injected oxygen consumed in the process. The question we pose in this presentation is: how far can this be stretched? There is certainly a limit – however, which phenomenon determines the limit and at which point is not always clear.

In order to optimize processes or to conceive optimal new designs, these phenomena need to be understood and implemented in detailed modelling software, e.g. CFD. Relatively well understood limits are set by splashing, where a too energetic gas stream will lead to difficulties to contain the liquid in the vessel. For a new design, building a tall vessel, as a TSL, can be a solution. The overall heat balance is another limit – to keep wall temperatures under control, losses should be balanced to heat input. Nevertheless, an excess of heat may be an opportunity for the treatment of more secondary materials.

At microscopic level, the reaction speed itself might be a limiting factor, although it is a general and often valuable assumption that local equilibrium is obtained at high temperatures. For a heterogeneous reaction between liquid and melt, this would mean the interface is at equilibrium, and the mass transfer becomes a key constraint. Whether mixing in the bath or diffusion in the gas boundary layer then becomes the limiting factor, may depend on whether an impurity in the melt or the main compound is involved in the reaction.

A factor which should not be overlooked is the heat transfer. Our simulations indicate that the time needed for heating the gas can be similar to that for diffusion in the gas phase. Depending on whether an exothermic or endothermic reaction is concerned, and whether a cold, combusting, or hot gas is injected, the heat transfer may work differently. Shrouding and supersonic injection, with the cooling expansion, may further complicate the matter. This presentation discusses some of the thermodynamic and flow aspects involved and looks forward to the modelling and validation planned in InsPyro's internal research.