Hydrogen Plasma Smelting Reduction, HPSR

Scale-up potential of the hydrogen plasma smelting reduction process was assessed during ULCOS first phase. The results of a lab scale reactor were not enough to evaluate the process feasibility versus other introduced coal based smelting processes that showed promising potential in CO_2 mitigation.

Scale-up scenario

The defining characteristic of the hydrogen plasma process is the absence of direct CO_2 emissions due to the replacement of carbon by hydrogen as a reducing agent and plasma as an electrical energy source. Relying only on lab scale results, it was not possible to claim the maturity of the process. Therefore, the process was described within ULCOS as a futuristic process.

A scale-up of the reactor to *500 kW~2MW power level* would be needed to assess the arc stability, arc diagnostics and heat transfer under H_2 plasma. Moreover, a scale-up is important to adapt the facility for *immersed arc ore reduction* as an approach to handle the arc radiation in a non foaming slag process (HPSR). A final relevant motivation for scale-up is the application of *combined H_2 plasma and coal-oxygen injection* to develop foaming slag that would lessen the radiation to the furnace sidewalls.

SWOT analysis in figure 1 shows briefly the process features and the current situation.

Strengths	Weaknesses
▪ Low CO_2 iron making process ▪ Simple flowsheet ▪ Low slag generation ▪ Non post combustion process ▪ Low dust emissions	▪ High radiation to the furnace walls (non foaming slag process) ▪ Slag aggressiveness to the refractory due to its high FeO content ▪ Necessity of a gas tight operation ▪ High cost of hydrogen versus coal as a reducing agent
Opportunities	**Threats**
▪ Dedication to breakthrough steel making technologies for CO_2 mitigation ▪ Dedication to eliminating coke ovens, sintering and pelletizing plants ▪Hybrid application with coal-oxygen injection	▪ Existence of more mature coal based smelting processes with satisfactory CO_2 mitigation results and advanced state of development ▪ Immaturity of the existing transferred arc plasma technologies in steel processing

Figure 1, SWOT Analysis

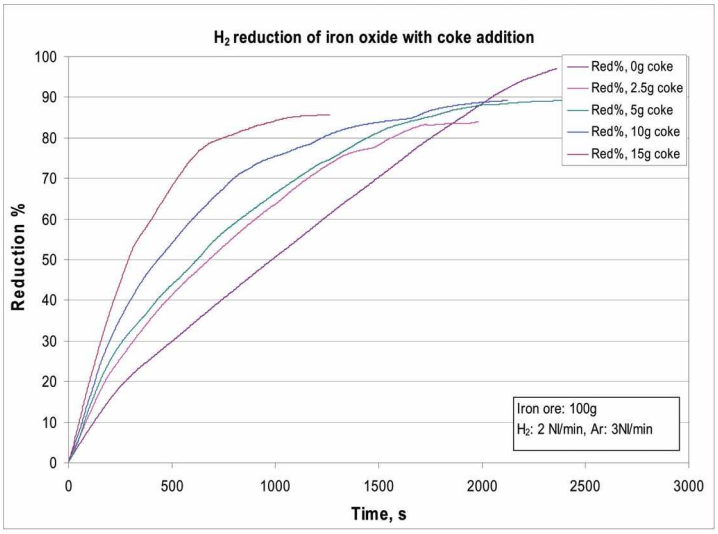

Figure 2, effect of coke addition on H_2 reduction behaviour

Experimental work

During the study of the process scale-up potential, deepening our understanding of the process was carried out via varying the control parameters throughout various test runs..

In one of those conducted test runs, the behaviour of combined coke-H_2 plasma process was investigated. It was aimed at assessing the plasma stability and the generation of foamed slag.

Figure 2 shows the coke-H_2 reduction behaviour versus H_2 reduction. The positive influence of coke on the reduction kinetics was clear. Moreover, the coke addition did not deteriorate the arc stability especially during the beginning of the experiment where the slag was relatively foamable due to the high generation of CO. However, smooth coke reduction has not been practiced in the conducted batch-wise experiments. It is presumed that this was due to the partial oxide melt solidification faced by the non even heat distribution caused by plasma.

Hybrid application of H_2 plasma with coal/coke-oxygen injection would be a potential smelting reduction process where the high arc radiation could be ruled out.

Recent research work

- Plasma smelting reduction of iron oxide by methane-argon gas mixture
- Influence of gases (CO, CO_2 and H_2O) on the kinetics of hydrogen plasma reduction
- Reduction behaviour of pre-reduced ores (magnetite, wustite equivalent)
- Reduction of iron oxide via tungsten electrode
- Preparation for continuous feeding ore experiments

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