Application of an Off-Gas Analysing System to Control Oxidation during Stainless Steelmaking in an EAF

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During stainless steelmaking in the electric arc furnace at Deutsche Edelstahlwerke GmbH, oxygen is injected to oxidize unwanted tramp elements mainly carbon and silicon. Unfortunately the injected oxygen also oxidizes valuable elements such as chromium and iron, which causes an economical loss and has a negative environmental effect. Since the temperature and dilution techniques to minimise chromium oxidation are seldom applied in the electric arc furnace, a new strategy to minimise chromium oxidation has to be developed. This paper proposes a new strategy which involves the use of a continuous off-gas analysing system to minimise chromium oxidation by monitoring the oxidation products in the off-gas, i.e. CO and CO_2. During stainless steelmaking in the electric arc furnace, for which initial carbon and silicon input cannot be precisely known due to imprecise scrap analysis, the installed off-gas analysing system should provide precise information concerning an efficient oxygen injection. This would then directly prevents excess chromium and iron oxidation. A continuous off-gas analysing system installed at Deutsche Edelstahlwerke GmbH delivers a promising result for future applications. During the plant trial, the efficiency of oxygen injection as well as the chromium and iron yields were increased.

Keywords: chromium scorification, stainless steel, off-gas analysing system, electric arc furnace

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Introduction

Oxygen is injected during stainless steelmaking in the electric arc furnace, EAF, to oxidize unwanted tramp elements, mainly carbon and silicon, to the target level for tapping. Unfortunately, silicon and carbon oxidation by a high volume flow rate of oxygen injection is accompanied by an extensive chromium oxidation from liquid steel to slag. This is due to the less noble property of chromium, i.e. its higher affinity to oxygen and oxidation at lower oxygen activities. Approximately 97% of all chromium loss during EAF-based stainless steelmaking takes place in the EAF [1]. Stainless steel producers have to minimise chromium loss during stainless steelmaking in the EAF due to its high price. Apart from the economical reason, chromium oxidation during stainless steelmaking should be minimized, since the formation of Cr species in leachates of EAF slag deposits and dusts has a negative environmental effect, which leads to the necessity for special measures and causes an additional cost during the EAF process.

Known metallurgical strategies to decrease chromium oxidation during oxygen injection into liquid steel such as operation at a very high liquid steel temperature, decrease of the CO activity by vacuum technology or by dilution with the injected argon gas, are not applied in the EAF. A new strategy to increase the efficiency of oxygen injection, which then directly decreases the chromium and iron loss to slag, has therefore to be developed. This new strategy is performed by controlling the oxidation process during the refining period. Many research efforts have been dedicated to developing a good control system of elements oxidation during the refining process through an in-situ slag analysis, e.g. [2, 3]. Unlike the approach used in those studies, another approach is used in this research by monitoring the oxidation products CO and CO_2 in the off-gas. The off-gas analysing system will provide precise information to control the efficiency of oxygen injection and help indentify the critical points of silicon and carbon oxidation. The latter defines the end of the efficient oxygen injection and can be used to directly prevent excess chromium and iron oxidation.

Thermodynamic Simulation

The input data used in this simulation is an exemplary industrial heat at Deutsche Edelstahlwerke GmbH (DEW). The compositions of scraps, alloys, and slag additives before the start of the refining period are sorted according to their chemical composition (**Table 1**). The Factsage thermodynamic databases [4] are then used to generate a free energy data file for the set of elements used and their corresponding phases. The amount of oxygen injection was input as a step change with the amount injected increasing by 100 kg O_2 during each step. After the equilibrium steel and slag compositions as well as each corresponding mass are determined by the thermodynamic simulation, the mass of oxidized elements are presented as a sum of all oxide forms for each element (**Figure 1**).

Since the results of the thermodynamic simulation are to be compared to the measurement data of the off-gas analysing system, the discussion concerning the results of

