Steel Cleanliness Quantifications in Molten Steel, Slabs and Coils for Process Optimizations

In steelmaking, indirect cleanliness measuring methods are preferred over direct measurements due to their simplicity. This article aims to quantify cleanliness in coils, ladles and in the inclusion banding in slabs in order to predict coil cleanliness results by steel plant direct measurements and to correlate the effects of steelmaking process parameters in the final product quality. This work managed to use ASTM E2283 as a cleanliness metric to validate cost-saving process changes without quality hindrances, later confirmed by E45 results.

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Introduction

Steel cleanliness measurements today are mostly simple indirect measurements, such as total oxygen, oxidized aluminum in steel (Alox), slag composition, submerged-entry nozzle clogging and nitrogen pick-up, and quick and highly punctual direct measurements such as E45, EN10247 and ISO 4967. This is due mainly to the time-consuming characteristic of extensive sampling and of more robust and precise direct measurements, for instance laboratory analysis as in scanning electron microscopy (SEM). The attempts to break this status quo are not new; along the years, attempts to turn around today's trends could be observed. Hüttenwerke Krupp Mannesmann (HKM)'s Silenos and SMS's HD Scan are both examples of high investment in the pursuit of representative sampling through the analysis of big area surfaces in relative short amounts of time.

With low marginal investment, this work saw the opportunity to apply SEM and the Gumbel extreme value distribution, used by ASTM E2283, to attempt to deterministically rate the cleanliness of steel heats and use those results to predict the results measured by the client's results in the coil. Process changes such as calcium treatment removal, quality enhancement of exposed interstitial-free (IF) grades, offheat upgrades and forced oxygen opened slab upgrades were measured in standard conditions and in the conditions of interest to optimize steel processes and increase production yield.

This work aims to share the results and lessons learned in a step-by-step trial-and-error pursuit of reaching a deterministic and large-scale reproducible testing method to measure steel cleanliness and to predict coil quality.

Discussion

Steel Cleanliness Measurements

To deterministically measure cleanliness in steel is still an ongoing challenge without a dominant market solution. For coils, ASTM E45 is widely used as it's a simple and fast method but, for starters, has a human factor and even the improved ASTM E2142, which is essentially the E45 performed automatically by an SEM program, still has a large variance in between samples. EN10247 and ISO 4967 share similarities with E45 and share similar issues.

Furthermore, to trace back a coil defect origin back to the slab production is extremely complex, as the