Inclusion Characterization of Titanium-Stabilized Ultralow-Carbon Steels – Impact of Oxygen Activity at Deoxidation

The automotive industry has continuously increased its requirements for surface quality of finished products, and in this respect, the challenges to produce cleaner steels have increased substantially. Particularly, Ti-stabilized ultralow-carbon (TiSULC) steels find applications for exposed automotive parts and are produced under stringent quality control conditions. These steels are also known for their clogging tendency due to both endogenous and exogenous inclusions. Sometimes the steel cleanliness, defined by either total oxygen content or inclusion density in tundish samples, is also compromised due to minor variations in the secondary refining practices, leading to downgrading and rejection of an entire heat or significant tonnage from the heat. One indicator, which was used to determine the relative steel cleanliness at an ArcelorMittal steel-producing plant, was the oxygen activity before steel deoxidation at the Ruhsthal Heraeus (RH) degasser. If the oxygen levels were higher than 750 ppm, the TiSULC steel heats were automatically downgraded. Therefore, a project was initiated to determine if steel cleanliness is directly related to the variable oxygen activity before steel deoxidation. This project also analyzed the effect of “late temperature correction” at the RH degasser on steel cleanliness. Late temperature correction is defined as events when the heats are either reheated or cooled after deoxidation or Ti alloying during RH treatment.

However, before initiating the above-mentioned study, a separate benchmark study was conducted, in which samples from end-degasser treatment and tundish from several steel plants were examined for inclusion composition and morphology. The primary aim of this activity was to characterize inclusions present in the degasser and tundish samples of heats produced with standard conditions. The results of the benchmark study are discussed prior to the results of the main project, which discusses the impact of oxygen activity on steel cleanliness.

The background information on formation of different morphologies of alumina inclusions is reported elsewhere. The work of Waisai, Piellet, and Tiekink motivated this study. Recently, Tiekink, et al., concluded that morphologies of alumina inclusions from either deoxidation or reoxidation are similar — the clustering effect is likely the result of agglomeration or growth of smaller particles. Piellet, on the other hand, explained that the inclusion morphology changes from ladle to tundish; globular-faceted inclusions were more frequent in tundish and mold than in the ladles. Additionally, higher oxygen activities before deoxidation resulted in a smaller fraction of dendritic inclusions in end-degasser samples in that study. Cong, et al., showed in their research that alumina is the stable deoxidation phase in TiSULC steels; their morphology changes a long time after Ti addition, as Ti-bearing alumina inclusions revert back to pure alumina inclusions. Ende, et al., explained that the difference in inclusion shapes, in both laboratory and industrial samples, is a consequence of different growth mechanisms — the deoxidation process generates a gradient of Al and O in the bath that leads to complex, and likely competing, conditions for inclusion growth. In the present study, the focus was not to study the mechanism of formation of various morphologies of pure alumina and Ti-bearing alumina inclusions, but rather to find out which morphologies are present in the tundish samples with variations in oxygen activity before deoxidation, and if these could be detrimental to the surface quality of the product.

The explanation of inclusion morphologies is covered in the referenced literature. A brief summary follows to familiarize the reader. Globular inclusions are thought to be due to “ripening” of dendrites, compaction of agglomerated small inclusions, or local chemical variations in steel, and their shape is spherical without size restrictions. Dendritic inclusions are believed to be due to a high supersaturation of Al and/or O (initial deoxidation or reoxidation). They generally

After analyzing liquid steel samples using automated SEM and remelt button techniques, it was concluded that higher oxygen levels before killing do not necessarily correlate to an increase in inclusion content of heats. This work analyzes the effect of oxygen activity and temperature correction on inclusion population and steel cleanliness.

November 2011  ♦  59