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Implementation of Novel Tracing Techniques to Control Steel Cleanness in CO2-Neutral Steelmaking

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The European steel industry is urged to achieve CO_2-free production by 2050, as the iron and steel industry is a major contributor to global anthropogenic CO2 emissions and thus to global warming. The transformation of steelmaking will require established processes, such as the Electric Arc Furnace (EAF), and novel technologies, including Hydrogen Plasma Smelting Reduction (HPSR) and the Electric Smelting Furnace (ESF), to achieve crude steel production with near-zero direct CO2 emissions. Ongoing research mainly focuses on primary metallurgy, aiming to optimize the reduction process and increase the scrap rates. However, the quality of crude steel and the resulting requirements for subsequent secondary metallurgy have not yet been sufficiently quantified.
To ensure equal or even higher steel qualities under these evolving conditions, the application of tracing techniques is required to address causes by identifying the origin and understanding the formation of non-metallic inclusions (NMIs). Two innovative tracing approaches are the rare earth element (REE) fingerprint and the isotopic spiking with enriched stable isotopes. Both methods have different objectives in inclusion metallurgy. The use of the REE fingerprint technique enables the determination of the origin of NMIs without the addition of an external tracer by only measuring the natural concentration of REEs in auxiliaries and NMIs. Regarding the second approach, enriched stable isotopes are added to one component in the steel-slag-refractory system. By modifying the isotopic ratio of one potential source, it is possible to study occurring interactions without influencing the properties of the resulting NMIs.
These two tracing techniques enable the investigation of the impact of increased scrap rates and lower scrap quality on steel cleanness which is linked to higher tramp element content in steels. By now, the influence of the different tramp elements on steel properties such as steel cleannes is not fully known by today. Furthermore, these tracing approaches can also be applied to study the effects of modified input material mixes, alternative auxiliaries and alloying elements on secondary metallurgy. Accordingly, this study highlights the impact of tramp elements and underscores the importance and operational principles of these tracing methods for reliable cleanness assessment.

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