Transforming Continuous Casting with ICME frameworks and IoT Technologies

Abstract

Continuous Casting (CC) is a pivotal process for steel manufacturers, and the quality of the billet, bloom, slab, or thin slab it produces has a significant impact on downstream processing and the final product.

To reduce defects, modern steel mills are increasingly considering advanced technologies that leverage embedded sensors to gather real-time information across the casting value chain.

Metallurgical defects arise from the way in which the material solidifies as well as its associated flow-related challenges, while operational defects arise from the way the casting operation is carried out.

Optimizing the Continuous Casting Process

Continuous Casting (CC) is the crucial transition process between steel-making and rolling that converts liquid steel to a solid mass. To drive improvements in the CC process, steel companies must to view the problem from two perspectives—physical as well as operational.

Typically, breakouts—where the steel shell wall is too thin to support the liquid steel column above it—are the result of:

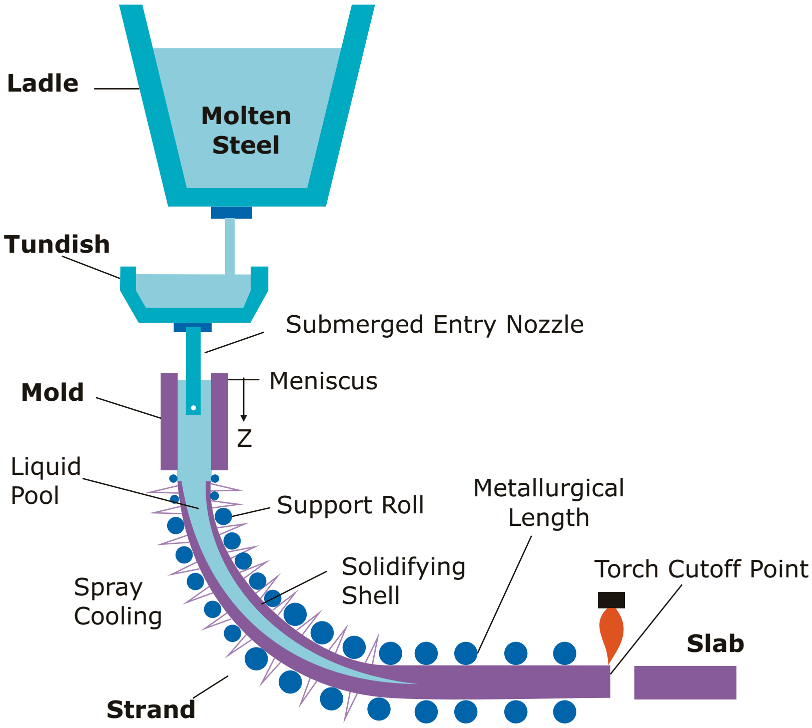
- Improper flow of cooling water to CC mold
- Disturbances in the strand cooling water spray system
- High withdrawal rate of the steel in strand
- The incoming steel liquid's extremely high temperature
- Deteriorated straightening rolls
- Excessive turbulence within the CC mold
- Sticking of shell to CC mold surface, cracks, slag, and scum entrapment

Production of a new grade of steel requires heavy investments of both time and money. Manufacturers, therefore, put in enormous efforts to stabilize the process parameters for the production of a new grade of alloy. Even a reduction in the number of trials by 2–3 can translate into huge savings. Process simulation helps reduce the need for running expensive trials and enables informed decision making.

The Integrated Computational Materials Engineering Framework

The Integrated Computational Materials Engineering (ICME) framework provides state-of-the-art methods for simulation-driven engineering. This enables analysis of the problem not only from a specific process standpoint (vertical integration), but also provides a holistic view of all the processes involved in the value chain (horizontal integration).

Deploying an ICME Approach for Producing Cast Slabs



The Continuous Casting process

An ICME approach can be used in different areas of the casting process to simulate and analyze the process to enable better outcomes:

Slab with required chemistry and inclusions below acceptable limits

Steelmaking involves addition of alloying and slag additives to produce the required chemistry and to remove excess dissolved oxygen from the basic oxygen furnace (BOF).

Computational fluid dynamics simulations coupled with thermodynamic and kinetics modeling delve deeper into inclusion analysis, capturing the melt-slag-air interactions and temperature variations during holding as it moves to the caster. Detailed analysis of these phenomena enables steel manufacturers to optimize design and process control - not only in the ladle but also in the subsequent downstream operations at the tundish and caster.

Additional casting aids include electromagnetic stirring (EMS) for breaking down the columnar structure and dynamic soft reduction (DSR) for minimizing the effect of center line segregation, computational fluid dynamics (CFD) simulations of flow behavior in the mold for insights into stabilizing the casting operation, and envisaging the installation of the Electromagnetic Braking (EMBR) to stabilize the flow.

Flow and temperature stabilization in the tundish

The steel melt with the desired chemistry is fed into the caster through the tundish, which has advanced features such as dams and weirs. An in-depth analysis can enable greater control of casting speed and superheat in the caster through flow and temperature modeling, and ensure higher purity steel through inclusion removal modeling.

Solidification, flow, and temperature in the caster

The melt enters the caster through the mold through the submerged entry nozzle (SEN), the design of which determines the stability of the solid shell of the continuous cast product. Currently, the industry lacks understanding of the solidification behavior of steel in CC under the influence of flow. Insights into phenomena such as segregation, columnar to equiaxed transition, and inclusion distribution in the presence of shrinkage, and bulging will help create additional casting aids.

Currently, the casting industry relies on past experiences in the design and development of newer grade of steels. A virtual platform to unify the models of the individual processes under one umbrella to enable seamless information exchange is still evolving. More focus is required in monitoring and optimizing the unit operations to meet rigorous specifications. In this context, the evolving Internet of Things (IoT) provides a promising avenue for online monitoring and self learning capabilities for reduced time to market.

Five Ways IoT Bolsters Continuous Casting

Five key ways in which IoT can improve the CC process through real-time data gathering:

- Using soft sensing techniques to predict the extent of center line segregation, which cannot be measured inline.
- Leveraging sensors to constantly monitor and provide feedback on optimal cooling control based on pressure data, which will determine the thickness of the solidifying shell.
- Enhancing the flow profile with flow measurements from sensors, which in turn affects the temperature field in the tundish.

- Utilizing the data collected from the mold, spray, and withdrawal zones to not only control the process, but to also monitor the health of the caster.
- Advanced controllers with self learning capabilities to achieve the prescribed control objectives in a near optimal manner

Conclusion

Accelerated product development and process optimization requires one to leverage state-of-the-art simulation techniques and IoT frameworks. An ICME approach can be used in different areas of the casting process to simulate and analyze the process to enable better outcomes. An IoT framework provides the robust infrastructure to enable online monitoring, real-time data gathering and advanced self-learning capabilities that can help reduce the time to market of new grades of steel.

References

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