Heatopt – an intelligent and holistic process-control system from Siemens VAI for optimized electric steelmaking

Mastering the Realm of Fire

Simetal EAF Heatopt is a holistic approach to electric steelmaking that allows fully automatic operations to be achieved on the basis of real-time measurements. The results: higher energy savings and improved process efficiency. The different aspects of this cost-saving EAF innovation are described in this article.
Even for an experienced operating staff, it is difficult to consider all of the relevant factors for assuring profitable electric steelmaking.
The Heatopt system offers a complete holistic approach that also includes upstream and downstream process steps.

Fig. 2: Main features of the holistic Simetal EAF Heatopt process model

Examples of integrated Heatopt submodels:
1) Heatopt (holistic energy and transparency optimizing)
2) Lomas (low-maintenance gas-analyzing system)
3) SAM (single-air measurement)
4) SonArc FSM (foaming slag manager)
5) SlagMon (slag monitoring system)
6) RCB Temp (Refining Combined Burner with temperature measurement)
7) SonArc CSM (condition-based scrap melting)
8) ECS (electrode control system)

Fig. 3: Main advantages of the Simetal EAF Heatopt system

Fig. 4: Simetal EAF Chargeopt automates and optimizes the charging of scrap into the electric arc furnace at Riva SAM Neuves Maisons, France
Most control solutions for the EAF deal only with specific subsystems: burners, electric-arc power, postcombustion and carbon injection. These independent subsystems are usually regulated by time or energy factors. However, an isolated approach toward achieving automatic operation can lead to a waste of resources, such as electrical power and chemical-energy input. Even for an experienced operating staff, it is difficult to consider all of the relevant factors for assuring profitable electric steelmaking. Simetal EAF Heatopt from Siemens VAI supports an optimized furnace control by simultaneously taking into consideration all measurement values and prevailing conditions (Figure 1).

Model description and benefits

Heatopt responds to continuously changing process conditions in the EAF such as different scrap compositions and arrangements from charge to charge. Such changes cannot be managed by means of conventional non-dynamic setpoints where rigid control diagrams based on time and energy are used. Furthermore, the use of sophisticated measurement techniques and condition-monitoring systems is required in order to achieve a deeper understanding of EAF processes.

Figure 2 shows the main features of the Heatopt process-control system and the associated submodels, which provide a dynamic view of the process in addition to material and energy flows. Scrap and material handling, as well as energy recovery, are included in the system. The Heatopt system thus offers a complete holistic approach that also includes upstream and downstream process steps. This, combined with intelligent control algorithms and process guiding at a high level of automation, provides the operator with the ability to fully handle, modify and optimize electric steelmaking operations.

Heatopt manages the electrical and chemical power input of the EAF applying closed-loop control. It regulates the transformer and reactor rates and the impedance setpoint on the basis of real-time process conditions. Continuous monitoring of the furnace offgas composition, offgas flow rate, and the level and distribution of slag are taken into account. From this data, Heatopt optimizes the input of natural gas and oxygen for refining and postcombustion, as well as carbon and oxygen for slag management. Additional benefits of the system include the monitoring and control of greenhouse gas emissions and improved safety that is achieved by the detection of potentially hazardous conditions such as water leaks in the furnace (Figure 3). Different features, components and benefits of Simetal EAF Heatopt are described in more detail in the following.

Automated charging

A recently designed laser-based measuring system known as Simetal EAF Chargeopt enables the scrap bucket on the transfer car and the location of the charging crane to be precisely positioned, ready for charging (Figure 4). The bucket is automatically hooked by the crane, lifted from the car and transferred to the furnace, where automatic scrap charging takes place. This operation is directly linked to furnace control, especially to the roof movements, to minimize the charging time.

Following the “next bucket” signal from the Heatopt control system, scrap is located and the bucket charged on a just-in-time basis according to the melting progress. Scrap-yard management is also closely coordinated with the EAF melting process. Simetal EAF Scrapopt, a new automation system for scrap yards, obtains its information from Heatopt, while the charge calculation provides the correct scrap composition and scrap layer sequence ready for the automated charging control system.

Melting progress

Melting is supported by tools to measure and monitor temperature, melting progress, offgas composition, possible water leakage and tapping control. A new contact-free temperature-measuring system, Simetal RCB Temp, is fully integrated into the long-established Refining Combined Burner (RCB) technology (Figure 5). As such, it is no longer necessary to insert lances through the slag door. Strict control of the furnace temperature by control models is the basis to achieve consistent process operations and repeatable results, enabling the exact tapping time to be predicted during furnace power-on. Benefits can be summarized as follows:

Benefits of RCB Temp

- Reduced operating costs and required consumables
- Substantially increased personnel safety
- Higher furnace productivity with reduced power-off times
- Consistent process parameters for repeatable results
- Decreased energy consumption through accurate determination of the ideal furnace tapping time

SonArc CSM (Condition-based Scrap Melting), an add-on for the electrode control system, observes in real time the meltdown behavior inside the furnace and adapts the electrical setpoints to provide process-oriented control of the electrical power input. It also determines the optimal point for charging subsequent buckets of scrap and provides real-time visualization with the potential to show any loss of arc shielding resulting from scrap movements such as scrap cave-ins.

For optimum slag foaming, SonArc FSM (Foaming Slag Manager) controls carbon and oxygen injection. Slag height and distribution inside the furnace are monitored and controlled to cover the arcs, thus minimizing arc radiation and
therefore reducing refractory wear. It also enables optimized furnace operation during the flat-bath period.

Both SonArc modules are based on the same hardware components, which minimizes costs associated with installation, maintenance and spare parts. Furthermore, both systems monitor conditions inside the furnace by analyzing structure-borne sound emissions and the spectrum of secondary currents. A combination of these characteristics determines the factors for totally automated furnace operation from scrap meltdown to steel tapping (Figure 6).

### Offgas analysis
Simetal Lomas uses a patented low-maintenance gas-sampling probe to analyze gas composition for furnace control and explosion prevention. The probe is positioned at the center of the duct diameter to ensure true offgas analyses of CO, CO₂, H₂, O₂ and CH₄ by avoiding peripheral air ingress and eddies that trap older offgas (Figure 7). Already well proven in more than 140 LD (BOF) converters, the Lomas probe was adapted and improved to withstand highly aggressive EAF offgas. Modifications were made for greater abrasion resistance, reliable tip cleaning and cooling, and reduced thermomechanical stress. A maintenance check is recommended only every three months and the probe life is around two years at a 99% availability.

### Water leakage detection
The Lomas probe also detects any increase in humidity of the offgas, which can point to a water leak in the furnace or in the offgas stack. Simetal Lomas detects possible water leaks in the EAF in two different ways simultaneously:
- Water dissociated into H₂ and O₂
- Water that leaves the EAF as a vapor, as indicated by a humidity sensor

While measuring dissociated water is a well-known approach, the additional strategy of measuring vapor in the gas is new. This not only offers redundancy should one sensor fail, but also increases validity of the results in case of sensor contamination, thermal drifts or aging.

### Slag detection at tapping
Minimizing slag carryover is essential for higher steel output and improved steel quality. Knowledge of the slag condition can also contribute to reduced additions of deoxidizing and alloying agents as well as minimized metal re-phosphorization and improved steel desulfurization. When the amount of slag carryover is reduced to a minimum, steel analyses are far more accurate, and the lifetime of the steel ladle refractory is also improved.

The thermographic slag-detection system, Simetal Slag-Mon, provides an accurate method of assessing the tapping stream. Various radiation emissions in the infrared range are conveyed by fiber-optic cable for continuous monitoring by an image-processing algorithm, making it easy to differentiate between steel and slag. An alert signal is generated when slag is detected, which can be used to control the shut-off device on the taphole.

### Post-steelmaking processes
The direct link to EAF post-processes, such as energy recovery solutions and ID fan control, completes the holistic approach. While taking into consideration the furnace pressure and possible false air measurements by the Lomas system, the system regulates the ID fan suction power. This ensures constant furnace pressure at around 10 Pa and avoids an over-oxidized furnace atmosphere. The result is reduced electrical energy consumption by the ID fans and lower electrode consumption, as the furnace atmosphere contains more combustible CO.

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**Proven benefits of Heatopt at SDI Roanoke**

- Decrease in gas and oxygen consumption by 15%
- Decrease in carbon consumption by 5%
- Productivity increase by 3.6%
- Lower conversion costs by more than $2/ton of tapped steel

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**First industrial reference**
The first industrial installation of the Simetal EAF Heatopt system was at U.S. steel producer SDI Roanoke (company of Steel Dynamics, Inc.), Virginia, in 2012. It consists of the Heatopt control package, the Lomas analyzing system and a slag-detection unit. The main benefits achieved with the process-optimization system include a decrease in gas and oxygen consumption by 15%, an average decrease in carbon consumption by 5%, and a productivity increase by around 3.6%. This has resulted in lower conversion costs totaling more than $2/ton of tapped steel.

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Fig. 5: The contact-free temperature measuring system Simetal RCB Temp is fully integrated with the Refining Combined Burner shown in the figure.

Fig. 6: Real-time SonArc vibration observation during melting (left using CSM) and flat-bath period (right using FSM).

Vastly improved EAF process control with Heatopt has resulted in cost savings of more than $2/ton of tapped steel for a U.S. electric steel producer.

Fig. 7: Positioning of the Simetal Lomas offgas probe at the center of the ducting improves offgas analyses by avoiding peripheral air ingress and eddies that trap older offgas.