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Source: © Saarstahl AG

Model-based dynamic monitoring and end-point control of converter process online in PSI*metals*

Optimised use of energy and resources

Producing steel in a BOF converter is a very expensive and energy-intensive process. Energy consumption is influenced by various chemical, physical and thermal factors during treatment; the same is true of material usage in terms of the amount of materials added and the timing of these additions. For optimal energy and resource efficiency, the provision of online information about the actual and predicted process behaviour is required. The dynamic process model developed by the VDEh-Betriebsforschungsinstitut (BFI) for online monitoring and control of the converter process has been integrated into PSI*metals*, allowing a heat-individual adaption of optimal process conditions. First results are now available from its use at the Saarstahl AG steelworks.

Energy and resource usage can be optimised by precise control of the blowing process and by managing the amount of added materials and the timing of these additions (see "BOF converter process" box). The aim is to achieve the target values for steel and slag analysis (particularly regarding carbon and phosphorus contents) and the tapping temperature as accurately and cost-effectively as possible.

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BOF converter process: Crude steel is produced by charging hot metal and steel scrap into the converter and adding slag formers. Oxygen is blown into the molten metal through a top lance, while inert gas is injected via nozzles in the bottom of the converter to stir the heat. Thereby carbon and unwanted impurities like silicon and phosphorus are combusted and removed via waste gas or slag. This oxidation process, which reduces the carbon content of the hot metal to the required value for steel, delivers the necessary energy for the converter process to melt the scrap and other additions and to bring the heat to the desired tapping temperature. Thus there is no need for an external heat supply.

► *Continued from page 1*

The converter process is normally controlled via static process models and fixed operating patterns for process gas inputs and material additions. With this control concept, an optimal operation of the process, taking into account dynamic changes during treatment of an individual heat, is not possible.

Dynamic process models have the edge

The dynamic on-line process model developed by BFI for the BOF converter calculates the steel temperature and the steel and slag analysis cyclically during the heat treatment.

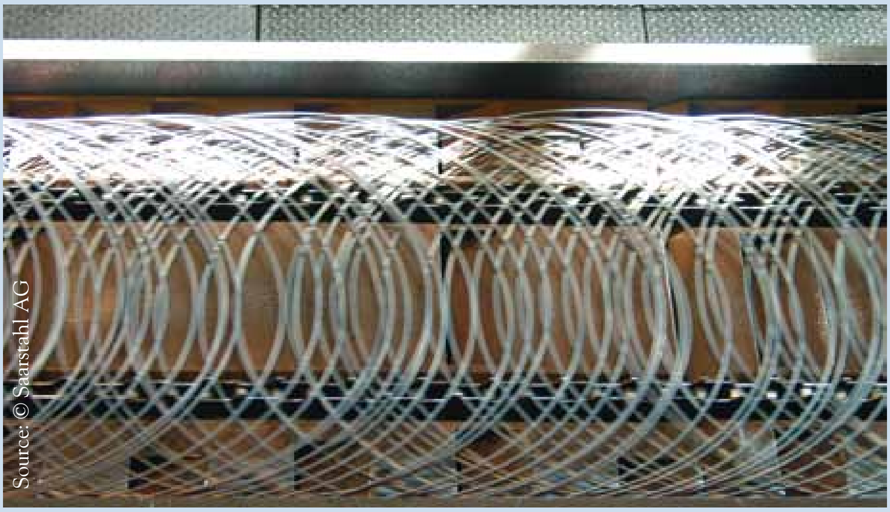
The temperature of the heat is balanced by taking account of the energy introduced during the chemical reactions, the energy losses due to thermal radiation, heat conduction and off-gases, and the energy needed to melt scrap, lime and other material additions. The model calculates the steel and slag analysis on the basis of thermodynamic equilibrium states, taking account the enthalpies of the different oxidation reactions rates for decarburisation, dephosphorisation and combustion of metallic elements. Off-gas measurements can optionally also be used to reconcile the thermodynamic calculation of the molten heat state, e.g. with regard to the start of the final phase of decarburisation, when the CO content in the off-gas decreases sharply. The dynamic process model thus provides information on the current heat state, the prediction of the further heat state evolution and on the estimated end-point of the converter process.

Process models and production management combined

During the converter process, production management systems like PSI*metals* monitor and control all process phases by managing expert knowledge on the necessary treatment practices and their target values, and also monitor and automatically control the process as a whole.

The integration of the dynamic BOF process model into PSI*metals* makes it possible to take both cyclically measured process data (e.g. gas flow rates) and acyclic events (e.g. material additions, temperature measurements) into account online in energy and mass balance calculations. PSI*metals* can use this information to calculate target values for optimised control. This enables the provision of a number

Saarstahl AG specialises in the production of wire rod, steel bar and semi-finished products in various grades. The basic oxygen steel making plant in Völklingen (Germany) has three BOF converters, each with a tap weight of 165 t, with an annual crude steel production volume of 2.53 million tonnes (2008).



of different online functions, including process monitoring, dynamic endpoint control and comprehensive dynamic optimisation of process control:

- *Process observation:* The current heat state in terms of temperature, weight and analysis of steel and slag is continuously observed online throughout the entire BOF treatment, i.e. from charging of the hot metal up to the start of tapping.
- *Dynamic endpoint control:* The further heat state evolution can be predicted, assuming that process conditions (gas flow rates) remain constant. This allows calculation of the possible endpoint of the oxygen blowing, at which the predicted carbon and phosphorus content falls below a certain threshold and the target temperature is expected to be reached.
- *Optimised process control:* Changes of the heat state under varying operating conditions can likewise be predicted. These predictions can be used to calculate dynamic target value corrections (for oxygen blowing, heating and cooling additions, slag former additions) for optimised process control, taking into account the tolerances stored in PSI*metals*.

Online process monitoring uses all available process data to continuously recalculate the steel temperature and the steel and slag analysis. This allows significantly improved prediction accuracy in comparison to static calculations. The dynamic model calculations integrated into PSI*metals* thus support optimal process operations over the entire treatment period to achieve the target values for the

Preparation	**Hot Metal Desulphurisation** - Mg/CaC_2/Soda - CaO	
Main Blowing	**Charge Material Calculation** - Hot Metal, Scrap, Lime... - Oxygen	**Dynamic Process Observation** - T, C, P, Mn,... - Current State - Predicted State at End of Blow
	Off-Gas Analysis - Oxygen up to End of Blow	
Finishing	**Correction Calculation** (w.r.t. T, C, P, S, Cr) - Oxygen - Lime, LD-Slag	**Desoxidation** - Anthracite, Al
Tapping	**Tapping Alloy Calculation** - Alloying Materials	

BOF process models with main functions integrated into PSImetals at Saarstahl   Source: PSI Metals

ource: © Saarstahl AG

Source: © Saarstahl AG

temperature and chemical composition of the molten steel.

Online process control with dynamic BOF model at Saarstahl

During 2009/2010 PSI*metals* was implemented as the production management system at the Saarstahl AG steelworks. As part of this implementation process the dynamic BOF model developed by BFI was also integrated into the process control functions of PSI*metals* in close collaboration with Saarstahl, in addition to a conventional static converter model. The diagram shows the BOF process models implemented within PSI*metals*.

At Saarstahl the main blowing phase of the BOF process is controlled online by means of a static charge material model, an off-gas analysis model for endpoint determination and the dynamic process monitoring and prediction model described here. The implemented online process monitoring and control functions based on dynamic models make it possible to control the endpoint of oxygen blowing more precisely, especially with regard to the target phosphorus content, but also with regard to the target temperature and target carbon content.

Outlook: model standardisation and extension of functions

In the online system, i.e. in the integrated application of the dynamic BOF process model within PSI*metals*, the mass and energy balance calculations are monitored and adjusted after each BOF treatment. Differences between the calculated and measured amounts of oxidised elements and between the calculated and measured temperatures are used to determine correction factors for oxygen efficiency and the heat loss rate of the relevant converter. This allows to track and treat systematic changes in process conditions over a series of heat production cycles, which are not mapped by metallurgical models, by means of statistical methods.

This type of dynamic process model, with its historical adjustment of basic mass and energy balances, also offers the prospect of future use as a basis for all the functions involved in controlling the converter process, i.e. for charge material calculation, continuous process monitoring and dynamic process control. This would make the introduction, development and maintenance of BOF models within process control systems like PSI*metals* much easier and lead to a standardised approach to optimising the use of energy and resources in converter steelmaking.

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