Perfect Sinter—The Dream of the Blast Furnace Operator

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ABSTRACT

In modern blast-furnace ironmaking today, the sinter plant no longer can be seen as a separate production unit, but must be fully integrated with the blast furnace to generate the ideal burden for optimized production and cost efficiency.

This paper presents a number of design and automation solutions for sinter plants and blast furnaces which, taken together, allow these targets to be met. The proven results are demonstrated on the basis of several upgrading project examples.

INTRODUCTION

Modern blast furnace operation at high levels of productivity and high coal-injection rates is only possible using raw materials with consistent and uniform properties. As the main component used in the blast furnace burden, the production of high-quality sinter is decisive for assuring high and stable blast-furnace productivity with a simultaneously low consumption of reductants.

The performance of a blast furnace, its productivity and energy consumption not only depends on the quality of the burden, but also on the design features of the installed equipment and systems, their condition and the integrated process-control systems.

In this paper innovative solutions are presented which allow significant improvements in the performance of the sinter plant and blast furnace to be achieved.

HIGH-QUALITY SINTER

Ideal blast-furnace performance with respect to high productivity, low consumption of reducing agents and constant hot-metal quality can only be achieved employing a high-quality sinter with the following characteristics:

♦ Optimum grain-size distribution:
  ➤ Grain size between approximately 5–50 mm
  ➤ Harmonic diameter of >>10 mm
High sinter strength:
  ➤ Shatter Index (SI) = >92%
High reducibility
  ➤ Reduction Index (RI): > 65%
  ➤ Reduction Disintegration Index (RDI <3.15 mm): < 20%
High porosity
Softening temperature above approximately 1250 °C, depending on total burden mixture
Narrow cohesive-zone temperature
Constant FeO content in the range of 7%
Constant basicity B2 and B4 adapted to best suit the overall blast furnace burden

Another aspect to consider is that most blast furnaces operate using a mixture of sinter, pellets and lump ore. Pellets and lump ore, however, are normally marketed with specific chemical compositions and qualities. An advantage in the use of sinter is that the burden can be optimized by adjusting the quality and the ratio of the charged sinter in accordance with the composition and characteristics of the other burden materials.

Influence of Raw Materials on Sinter Quality

The production of high-quality sinter depends to a high degree on the chemical composition of the raw materials, especially with respect to the gangue content (SiO₂, MgO, Al₂O₃), interstitial water and the CaO/SiO₂ ratio of the sinter raw mix. Particle grain size is paramount in importance. Investigations have shown that fuel consumption at the sinter plant and hence the FeO content of the sinter increases with an increasing fines content with grain sizes < 0.1 mm and >8 mm.

The maximum grain size of the additives should be limited to approximately 2 mm with consideration to the targeted sinter strength, reducibility and porosity.

Influence of Sinter-Plant Operational Parameters on Sinter Quality

A decisive precondition for the production of high-quality sinter is a homogeneous sinter raw mix of high permeability. All additives should be uniformly distributed throughout the mixture. A high and uniform permeability allows the bed height on the sinter machine to be increased, which accordingly lowers the fuel consumption for the sintering process. Excessively high sintering temperatures can thus be avoided, positively contributing to the sinter strength, the reducibility of the sinter and indirectly, the FeO content, among other benefits. Sinter with an FeO content of less than 7% can only be produced with a sinter-machine-bed height of approximately 600 mm. In this context it is important to mention that the proper equipment must be installed to ensure that the fuel concentration continually decreases from the top to the bottom of the sinter raw mix layer in order to prevent excessive sintering temperatures.

An increased sintering time also has a positive influence on the mean diameter of the sinter product. The sintering time is influenced by the permeability of the raw mix and by the suction pressure. Lowering the suction pressure, however, decreases the productivity of the sinter plant.

The distance of the burn-through point from the sinter machine discharge has a direct influence on the sinter-machine capacity, the average FeO content of the sinter and the mean
diameter of the sinter product. The ideal positioning of the burn-through point is a compromise between the productivity and quality targets, however, the sinter quality is paramount in importance for blast furnace operation. If the production of high-sinter quality leads to a lack of the required sinter quantity, then this situation can be rectified with relatively low investment expenditures, as outlined in the next section.

Influence of Sinter-Plant Equipment on Sinter Quality and Quantity

The production of homogeneous sinter already commences in the blending beds and continues to the storage and proportioning bins. Special attention must be placed on the design of these facilities to prevent undesirable material segregation. For ideal results the operation of the proportioning, dosing and weighing system of the storage bins has to be computer-controlled on a real-time basis.

Because the mixing efficiency of conventional mixing/rerolling drums is limited, especially with respect to the uniform distribution of additives and fuels with grain sizes of < 2 mm, the following improvement solutions are available:

♦ Self-cleaning shovels for conventional mixing drums—successfully applied at the sinter plant of voestalpine Stahl in Linz/Austria
♦ Replacement of conventional mixing drums with the "Intensive Mixer" (Figure 1)—a state-of-the-art mixer for production of a sinter raw mix with optimum homogeneity and permeability. The world's first installation was at the sinter plant of voestalpine Stahl Donawitz/Austria.

Improved sinter quality and increased productivity were the results at both of these sinter plants.

![Figure 1: Intensive Mixer Installed at voestalpine Stahl Donawitz, Austria](image)

Controlled charging of the sinter raw mix to the sinter machine leads to the following improvements:

♦ High and uniform permeability of the raw-mix layer for the production of high-quality sinter at a low electric energy consumption rate
♦ Controlled segregation of the sinter raw mix during charging to the sinter machine to ensure the desired grain size distribution from the top to the bottom of the sinter bed
♦ Decreasing concentration of the fuel from the top to the bottom of the sinter bed to avoid an excessively high sintering temperature

The sinter machine pallets have to be designed to minimize false-air intake and therefore should be equipped with rim-zone covers to ensure good sinter quality also along the sidewalls.

The ignition furnace should be equipped with roof burners to ensure intensive and efficient ignition of the complete surface area of the sinter raw mix layer. Use of a sophisticated control system prevents excessive ignition temperatures and thus saves energy.

The main task of the process control system of a modern sinter plant—which includes integrated process models—is to optimize all process parameters to ensure that the targeted product quality and sinter-plant productivity are met (Figure 2).

Figure 2: Main Features of Process Control for Sinter Plants

If as a result of the increased emphasis on the sinter product quality there is a corresponding decrease in the productivity of an existing sinter plant, cost-effective solutions are available which enable up to 20% higher sinter-production. This is exemplified by Pallet-Width Extension Technology of VAI, currently installed in seven sinter plants (Figure 3).

Figure 3: Pallet-Width Extension Technology
The next installations, including a simultaneous increase in the cooling capacity, will be executed at Sinter Plants No. 1 and 3 of POSCO Kwangyang Works, scheduled for April and June 2002 respectively.

**HIGH-PERFORMANCE BLAST FURNACE OPERATION**

**Blast Furnace Burden**

Modern blast-furnace operation at high levels of productivity is only possible by using raw materials with consistent and uniform properties. From the point of the blast furnace operator the main requirements placed on the burden focus on

- High permeability and homogeneity across all furnace temperature and reaction zones
- High reducibility of the iron oxide contents to promote short retention times
- Low content of tramp elements such as zinc, lead and alkalines to avoid process disturbances

The ideal burden is different for each blast furnace and depends on the specific production targets. Special attention must be placed on the following:

- Quality and consistency of burden and coke
- Significantly reduced hearth wear through improved tapping practices
- Ideal gas and energy distribution within the blast-furnace shaft based on computer-controlled burden charging
- Fully optimized and stable blast furnace operation based on the application of sophisticated process models and expert systems

**Blast-Furnace Equipment**

- **Stockhouse and Furnace Top**

  The stockhouse and blast-furnace charging system are the key facilities for attaining the desired burden distribution in the furnace. The stockhouse should be designed so as to allow for multi-fraction sizing of sinter and coke, including screened or unscreened undersize material, as well as the flexible portioning of different grain sizes of these materials. This is the basis for the efficient application of the bell-less-type charging system—the prerequisite for advanced blast-furnace operation today.

- **Tuyere-Injection Facilities**

  Exact control of the tuyere injection rates—particularly for coal—is decisive for a homogeneous temperature distribution and overall process conditions within the furnace hearth. In good injection practice the difference in the standard deviation in the coal-injection rate from tuyere to tuyere should not vary by more than 2%. Moderate oxygen enrichment of the hot blast is essential for careful control of the target value of the raceway flame temperature—important for stable furnace conditions.
• Tapping Practice

Careful monitoring of the wall-temperature, hearth drainage and tapping speed—ideally with the use of special process models—is important for preventing extensive hearth wear and for ensuring stable furnace operations, especially at high productivity levels with elevated coal-injection rates. Some operators report about problems in connection with taphole-length control at high furnace-productivity rates. However, the installation of high-speed hydraulic drilling machines in conjunction with the use of improved clays contribute considerably to enhanced taphole conditions.

Instrumentation

Modern blast furnace facilities are typically characterized by the installation of a large array of sophisticated and highly accurate sensors, instrumentation and laboratory equipment. This is the basis for the acquisition of quality data used for process control and automation and for evaluating key process parameters such as:

♦ Chemical and physical analyses of the burden materials on the basis of a reliable and online material tracking system
♦ Measurement of the actual coke moisture content for precise online coke-weight adjustments
♦ Chemical analysis of topgas and determination of topgas temperature distribution along the furnace cross section as well as burden-profile measurements
♦ Measurement of CO-, CO₂- and temperature distribution within the furnace shaft with the use of retractable in-burden probes normally inserted once per shift
♦ Accurate monitoring of stave temperatures and refractory conditions with the use of strategically placed thermocouples
♦ Hearth condition monitoring based on approximately 100 thermocouples installed in the hearth sidewall and bottom area
♦ Measurement of blast volume, temperature, humidity, oxygen enrichment, pressure as well as the quantity of injectants (oil, coal or gas)
♦ Calculation of furnace heat losses on the basis of accurate flow-rate and temperature measurements
♦ Detection of potential water leaks by flow or level measurements (safety assurance)

Process Control and Automation

A comprehensive integrated process-control system necessitates a well-organized and coordinated data exchange between all automation levels as well as with the work stations of the operators and process engineers. For a fully optimized blast-furnace operation the VAiron blast furnace automation system of VAI features three distinct automation levels. The process information management level collects, prepares and stores all relevant data for subsequent use. The process model level consists of a series of standardized mathematical models which are grouped into mass and heat balance models, special models and kinetic models. The third level—a closed-loop expert system—enables fully automatic control of key operational parameters (Figure 4).
Figure 4: VAiron Solution Packages for Optimized Blast-Furnace Performance

The ultimate target of highly sophisticated control systems and process models for the blast furnace is to optimize all cost-relevant factors with respect to the overall operational objectives in a fully automatic mode, i.e. with a minimum of interaction by operating personnel. Examples of key objectives include:

♦ Minimized consumption of reductants by accurate forecasting of the furnace thermal behavior
♦ Avoidance of critical situations such as hanging, slipping, scaffolding, gas channeling, etc., through an immediate counteraction by the system
♦ Stabilization of hot metal and slag parameters within defined tolerances
♦ Assurance of a uniform blast-furnace operational practice across all shifts
♦ Hearth-temperature monitoring and automatic ilmenite injection for remedial correction of excessive wear

Application of an online burden-distribution-control system is decisive to assure:

♦ Stable burden descent
♦ Optimized gas flow near the furnace wall (minimized heat loss)
♦ Elimination of inactive zones

A closed-loop expert system offered by VAI automatically fine-tunes the burden distribution without operator interaction. The expert system works on the basis of operational know-how stored in a database and implements the strategic operational management decisions 24 hours a day. The result is consistent and optimized blast-furnace operation and significantly reduced production costs.

PROJECT EXAMPLES

voestalpine Stahl Donawitz, Austria

The sinter plant of this integrated iron & steel works was modernized in the late 1990s. The conventional combined mixing and rerolling drum was replaced by a new "Intensive Mixer" and a new ignition furnace was installed. These improvements were carried out in conjunction with minor modernization work on the blast furnaces.
Results
- Increased sinter plant productivity by approximately 10%
- Improved sinter quality with respect to product strength and homogeneity
- Decreased blast-furnace-coke consumption by approximately 20 kg/t hot metal

Companhia Siderurgica de Tubarao (CST), Brazil

In a major sinter plant modernization project executed by VAI for CST a number of decisive improvements were implemented. A special highlight was the application of Pallet-Width-Extension Technology for increasing the width of the sinter machine from 5.0 meters to a world record of 5.5 meters.

Results
- Increased sinter production by more 15%
- Significantly improved sinter quality
- Reduced consumption figures of coke, burnt lime, ignition gas, electrical energy
- Increased sinter yield
- Improved overall blast furnace performance

voestalpine Stahl, Linz/Austria

With the installation of a closed-loop process-control system in combination with spiral charging outstanding improvements were achieved in Blast Furnace A of this quality-steel producer. Through the application of a fully automatic burden distribution system, 150–180 kg of burden fines (0–5 mm for sinter and pellets, 0–10 mm for lump ore) per ton of hot metal are directly charged into the blast furnace. With the unique spiral-charging system jointly developed by VAI and voestalpine Stahl the fines are charged close to the furnace wall to optimize the gas distribution and minimize heat losses.

Results
- Improved overall blast furnace performance
- Reliable and stable furnace operation
- Reduced raw material costs
- 100% charging of all stockhouse fines directly into the blast furnace (no fines recycled to sinter plant)
- Proven annual savings of up to 20 €/t hot metal

CONCLUDING REMARKS

With most blast furnaces there is an enormous potential for improvement with respect to productivity, energy savings, campaign life and hot-metal quality. Blast-furnace performance is crucially dependent on the burden quality and the condition of the blast furnace.

An ideal burden can be achieved to a large extent by the careful adjustment of the sinter quality in a modern sinter plant. It must be pointed out, however, that the benefits of a fully optimized burden can only be exploited when all blast furnace facilities, including the stock house and the charging, injection, tapping and process-control systems, operate efficiently and at peak performance levels. Advanced process models and expert systems are available
to ensure stable and precise control of the blast furnace with the simultaneous fulfillment of all quality, production and cost targets.

Finally, it is to be emphasized that the necessary investments for sinter-plant and blast-furnace upgrading are relatively small in comparison with the resulting cost savings and other benefits.

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