



PROCESS OPTIMIZATION ENABLES ENERGY SAVINGS FROM COKE MAKING TO CONTINUOUS CASTING¹

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Abstract

Optimization systems for different processes in the metallurgical industry from coke making, sinter plants, iron making to steel plants have been installed in numerous applications. Typical direct and indirect energy savings and their contribution to the total energy consumption per ton of crude steel are investigated. The basic principles of the different models and their impact onto the plant operation are described and completed by an outlook onto future developments. This paper emphasise the optimization system for coke plants, sinter plants and blast-furnaces.

Key words: Process optimization; Energy savings.

Resumo

Existem instalações de varias aplicações de sistemas de otimização para processos diversos na indústria siderúrgica, do processo de coqueria, sinterização, redução e aciaria. Os potenciais típicos de conservação de energia direta ou indireta e a contribuição de cada uma no consumo específico de energia por tonelada de aço estão sendo investigados. Os princípios básicos dos modelos diferenciados e o impacto na planta em operação estão sendo descritos e complementados com uma previsão para desenvolvimentos futuros. Este trabalho enfatizará esses sistemas de otimização para coqueria, sinterização e alto-forno.

Palavas-chave: Otimização de processo; Economia de energia.

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1 INTRODUCTION

The liquid phase, i.e. the area from the coking plant and sintering plant, the blast furnace and all the way up to the steel works, is responsible for roughly 85% of the energy conversion in integrated metallurgical facilities. The Ironmaking area is responsible for 70% of the energy consumption in an integrated Steel Plant. This amount depends among other things on the raw materials used, especially the share of scrap and the assignment of energy costs in auxiliary plants (e.g. consideration of energy costs as those for the supply of oxygen).

In the last years, increasing attention has been paid to these energy flows due to rising costs caused by increased demand and limited availability of lower-priced raw materials and considerations about legislative measures in order to reduce greenhouse gases.

Among the various levers to increase the energy efficiency of integrated iron- and steelmaking plants optimization solutions are attractive due to the relatively low investment costs.

2 TYPICAL SYSTEM STRUCTURE

2.1 Process Automation System / Process Control System

In addition to basic functions such as data acquisition from the field instruments and setpoint execution, technological controls (main control loops) are implemented in the basis automation system – specially for fast reacting controls and controls requiring a very high availability. Setpoints requiring complex model calculation are usually provided by the process optimization (level 2).

2.2 Process Information and Data-Management System

The data acquisition function preprocesses and stores the data from a broad spectrum of raw data sources including front-end signals, material weights, laboratory data, events, model results and cost data, etc. It validates and interprets process data and visualizes the results in Windows- or web-based graphical user interfaces. Data handling encompasses the chemical and physical data of the plant as well as the process history.

2.3 VAiron Expert System

For systems with a long response time and complex response behaviour (e.g. ironmaking plants) Siemens VAI developed the VAiron Closed Loop Expert System in close cooperation with the Austrian steel producer voestalpine. The core of the system is a diagnostic system, which is based on historical data, auxiliary calculations and actual measuring values, diagnoses the overall sinter-plant status and previous sintering conditions. Input data is checked for plausibility or compared to admissible limits in order to avoid erroneous diagnoses.

The major function of the VAiron expert system is to provide corrective actions by suggesting the modification of process variables. Each particular corrective action can be executed in closed-loop operation or in semi-automatic operation. In closed-loop operation the calculated set-points determined by the expert system are automatically transferred to the process-control system whenever a set-point change

occurs due to changing process conditions. The system performs all recommendations simultaneously and does not require any interaction by the operators. In semi-automatic operation the calculated set-points determined by the expert system are presented to the operator on the HMI (human-machine interface) of the process-optimization system. Within a certain time period, the operator has the possibility to acknowledge, change or refuse the recommendations.

3 COKE MAKING

Environmentally sustainable development is an important issue in coke production today. Pollutants are an inevitable by-product of the coking process. With good plant design and operation, however, emissions can be cut to low levels or eliminated altogether. Permanently increasing cost pressure in the iron and steel industry means that cost-optimized operation and highest production quality are the key factors also for competitive and profitable coke production. Therefore automation systems contributing to better energy efficiency and improved coke quality are continuously in the focus of research and development.

3.1 Coke Battery – Optimized Heating and Scheduling Operations

In controlling of a coke battery, the main objective is to keep the coking process stable and free from disturbances while producing coke of excellent quality. These priority studies must be achieved whilst taking particularly care of minimizing energy costs and environmental pollution, and ensure increased productivity and maximum battery service life. Applying constant and effective coking process control and optimization will attain these different objectives. In Siemens VAI, these objectives are attained by the Coking Process Management System (CPMS), which is a state-of-the-art level-2 control system to optimize the process control of the battery and facilitate the operators' work. By advanced process modelling for efficient scheduling of the coke oven machine operations and optimized coke oven heating, savings in fuel consumption by 2-5% and more uniform coke quality can be achieved.

3.2 Typical Total Energy Savings

Due to the stabilized heating and process operation significant energy savings can be achieved.

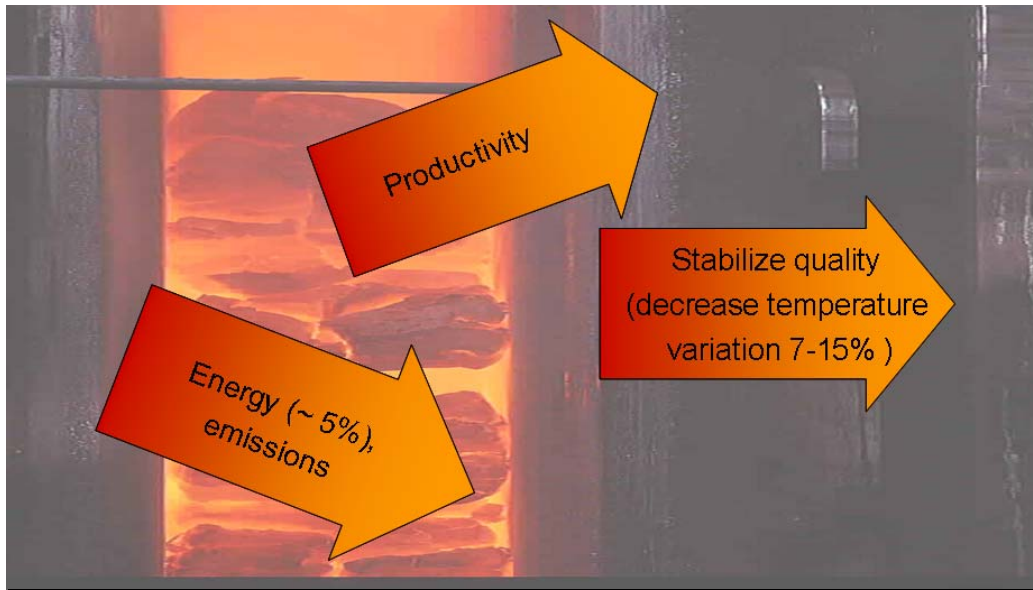


Figure 1: Typical benefits SIMETAL Coke coke making optimization.

4 SINTER PROCESS

Sinter VAiron is an advanced process-optimization system which extends from ore preparation in the blending yards, covers the production of sinter feed in the sinter plant, and takes into consideration the requirements of the blast furnace. The main overall target of the system is to achieve a high output of uniform sinter quality at low operational costs. This is accomplished by the application of a number of sophisticated tracking, diagnosis and control models and systems which are bundled within an overall expert system.

4.1 Sinter Expert System

In the sintering process, the sinter product must satisfy defined target values with respect to chemical and physical parameters. Sinter quality begins with the proper selection and mixing of the raw materials in the blending yard and sinter plant. The chemical properties are stabilized by an automatic adaptation of the raw material mix. An enhanced burn-through-point-control system which takes into account physical and chemical properties of the sinter mix is incorporated in Sinter VAiron. A key feature of the system is its capability to quickly react to process fluctuations and aberrant situations, such as an inhomogeneous mixture, poor surface ignition or incomplete burn-through of mix. This is achieved in closed-loop process control, resulting in smooth sintering operations and uniform product quality.

These include the quantity of sinter return fines, coke additions, productivity control, basicity of the sinter product, coke base in the raw sinter mix, the SO₂ content in the waste gas and the FeO content of the produced sinter.

4.2 Typical Energy Savings

There are 3 fields, where a sinter optimization can contribute to increased energy efficiency:

- The coke rate is minimized if (among other factors) the following process parameters are kept in an optimal range: raw mix moisture, strand speed,

- transversal burn through point and coke rate. The SIMETAL^{CIS} Sinter VAiron keeps the process close to this optimum.
- If the sintering plant represents a bottleneck in the production chain, an increase in production results in a reduction of fuel consumption in the BF due to the lower reductant consumption of the sinter in comparison with other burden materials.
 - Optimized control of the ignition hood will lead to reduced gas rates

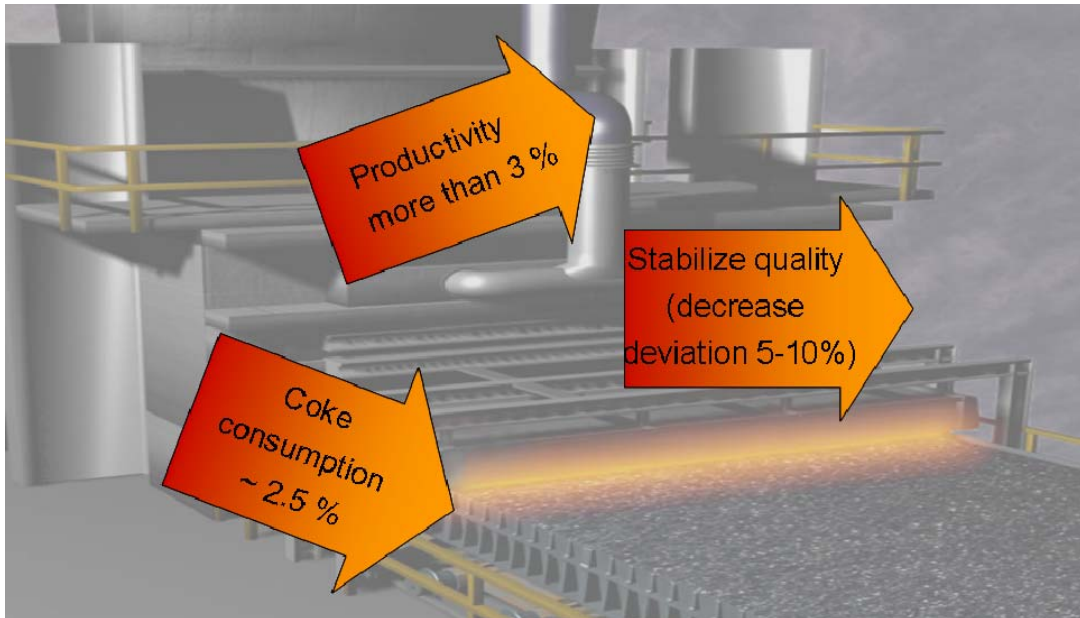


Figure 2: Typical benefits SIMETAL Sinter VAiron - sinter plant optimization.

5 BLAST FURNACE OPERATION

To enable standardized and optimal plant operation for various operating conditions a reliable process automation system was developed:

The VAiron expert system allows the blast furnace to be operated without the need for operator interaction. For example, control of the coke rate, basicity and the steam-injection rate are simultaneously and automatically executed in a closed-loop mode to ensure stable and consistent process operations at low production costs.

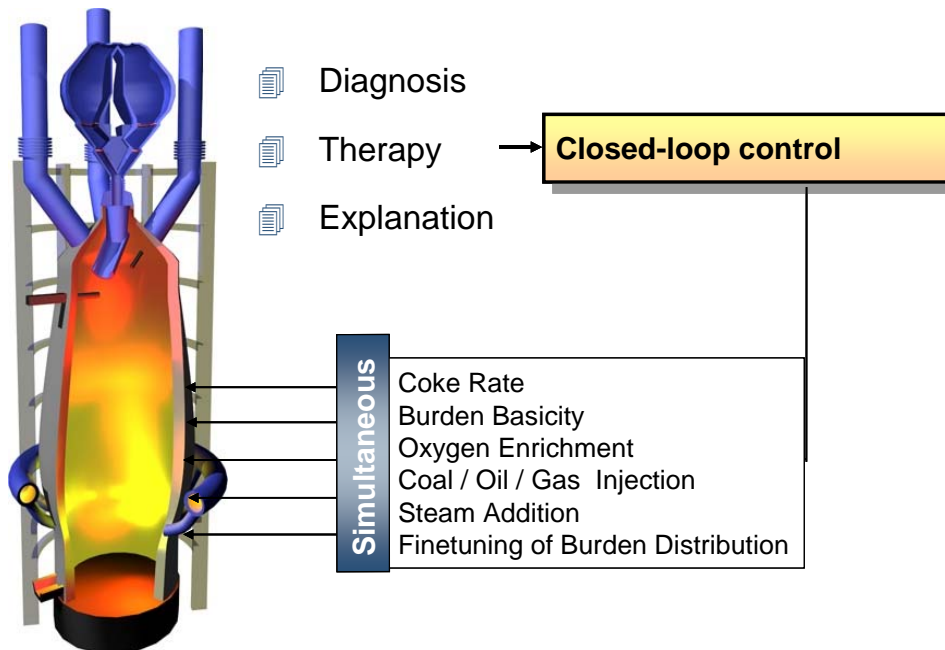


Figure 3. Closed loop control of blast furnace operational parameters

As the blast furnace expert system works with several process models to control, planning and maintain the system. The models of control are the burden control, burden distribution, shaft calculation, tapping management, hot stoves control, blast furnace supervision. The research and planning models are the kinetic process simulation, minimum fuel consumption, silicon & temperature prediction, cohesive zone and blast simulation. The maintenance models are balance plausibility, mass and energy balance, hearth lining monitoring.

The closed-loop control system will operate together with the models to predict, to make the diagnosis and to take the corrective action into the system. The expert system also works to prepare for a shutdown and start-up plan and for a PCI ramp up and down. The VAiron Tapping Expert System is able to standardize the casthouse management.

The VAiron system was first installed in voestalpine BFA, Linz, Austria in 1993 and the closed loop Expert System started operated in 1998. After that a number of companies around the world has been worked with the VAiron packages. Some results of the operation with this system are bellow.

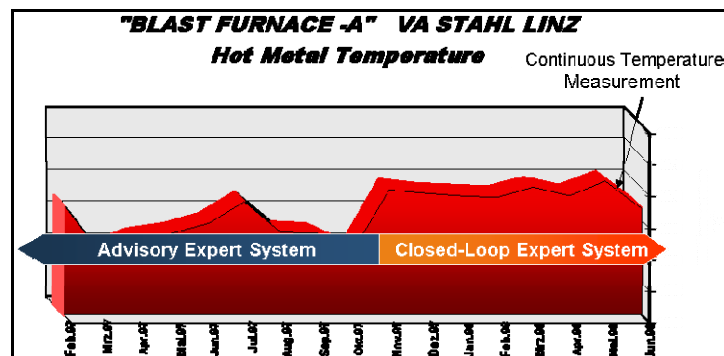


Figure 4: VA Stahl Linz hot metal temperature before and after the operation with closed-loop expert system.

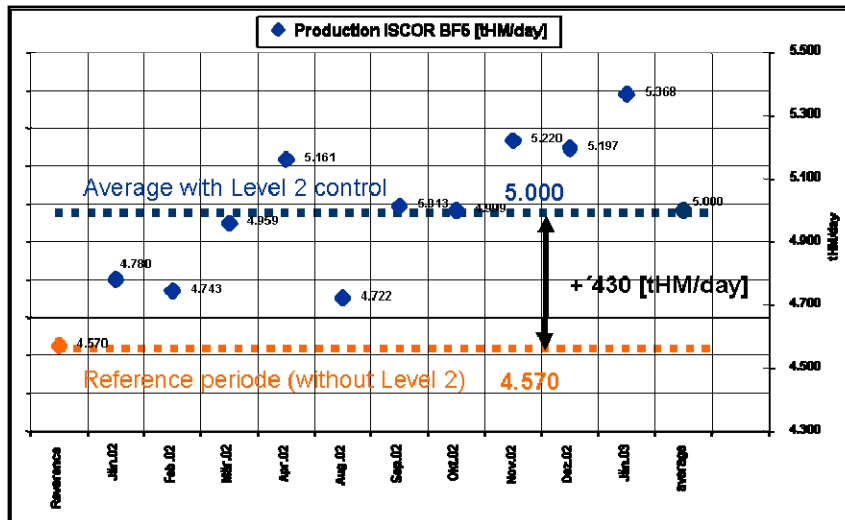


Figure 5: Results at ISCOR Newcastle, South Africa - Hot metal Production before and after the installation of level 2 control system.

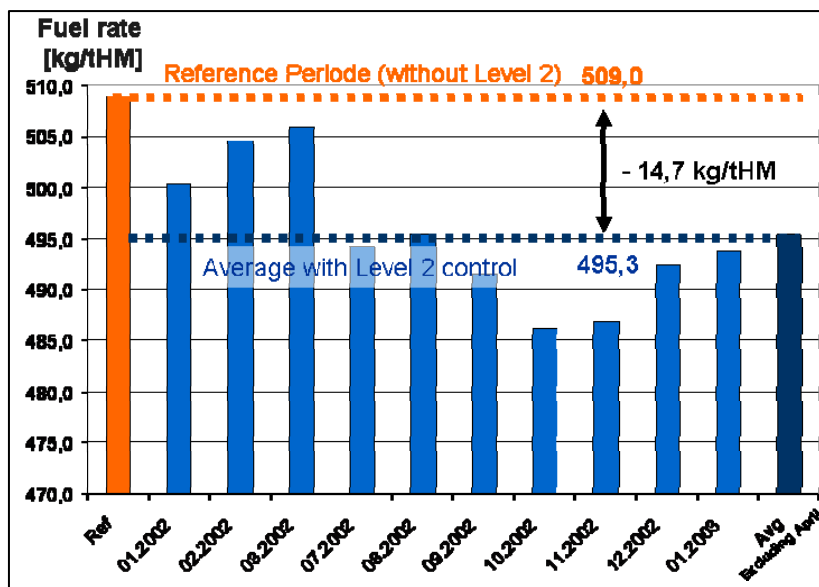


Figure 6: Results at ISCOR Newcastle, South Africa - Reducing agencies before and after the installation of level 2 control system.

One important components of the BF optimization will be described in more detail: the Fines Charging Concept.

5.1 Fines Charging

Burden fines with their small average grain size can heavily influence the gas distribution, pressure loss and the overall furnace performance.

On the other hand, all the fines being sent back and used in the sinter plant as sinter feed have been previously purchased or produced with the original intention of being used as coarse BF charging material. Thus the direct usage of fines in the blast furnace leads to an increase of the effective sinter plant production, and the existing price difference between coarse material and sinter feed material appears as an additional economic incentive. Voestalpine in Linz adopted an operation philosophy that allows making full usage of undersize material within the blast furnace without being confronted with the negative side effects.

At Voestalpine Linz BF A, all burden materials are transported via a conveyor belt to the furnace top. To make full usage of burden fines within the furnace, it must be guaranteed that the fines are positioned well apart from the screened material both on the conveyor and also within the furnace. The screened burden components can be transported to the furnace top also as burden mix to equalize the metallurgical properties of the different burden materials, but as well, a separation on purpose is also possible to make use of different properties if required. To position the materials properly within the furnace the process control system determines the precise schedule of discharging. To establish high fine volumes, the burden is discharged according to the “spiral charging method”.

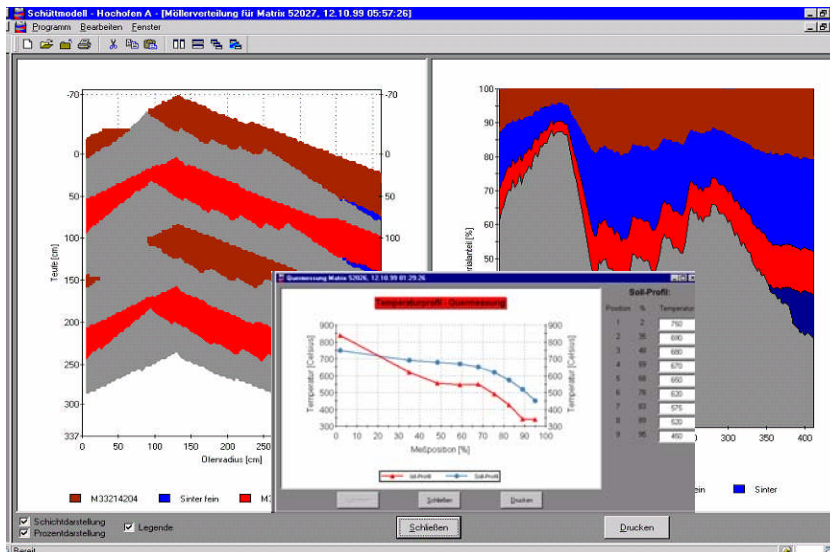


Figure 6: Burden Distribution Model.

The control of the exact distribution is done via the on line burden distribution model in combination with the expert system based on the actual descending behaviour of the furnace in order to control the permeability of the furnace.

5.2 Typical Energy Savings

The smooth and standardized operation leads to a significant reduction of the fuel rate.

Due to the charging of fines the re- sintering can be avoided, which directly saves coke in the sinter process.

6 HOT STOVE

The Hot Stove Optimization Model calculates the optimal heating strategy to ensure blast supply at target temperature at reduced energy costs. It is designed to optimize stove control in all common operational modes.

A predictive calculation of the changeover time leads to regular stove cycles. The self-learning model automatically indicates and compensates for measurement inaccuracies. The corresponding compensation factors can be used as a basis for specific maintenance. The standardized operation and additional security checks have a positive impact on the lifetime of the hot stoves.

6.1 Benefits of the Hot Stove Optimization

Economical and environmentally-friendly operation is supported.

Reduced amount of rich gas (e.g. natural gas, coke oven gas) due to increased efficiency and precise combustion is achieved

Early detection of burner or brick deterioration.

Extended lifetime of stoves due to:

- smoother operation with smaller band width for process parameters and strict preservation of limits
 - additional security measures (e.g. cross-checking of dome temperatures using flame temperature calculation).

6.2 Typical Energy Savings

The optimal energy load level depends on the reliability of all parts which facilitate the operation of the hot stove system, as well as on the bottleneck considerations and the stability and uniformity of the blast furnace operation. This level always represents a compromise between security of supply and energy efficiency

An optimal selection of the thermal condition will have the two following impacts: A direct one through the reduction of the combustion gas volume and an indirect impact through an increased wind temperature, which in turn results in a lower coke rate.

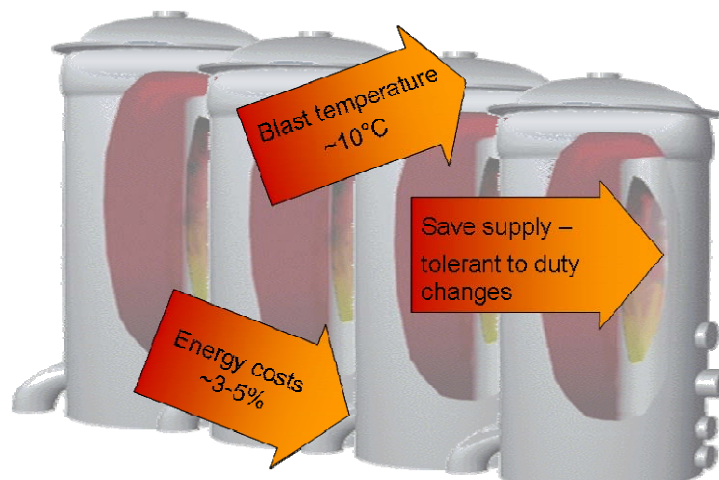


Figure 7: Typical benefits SIMETAL BF Vairon Hot Stove - hot stove optimization

7 SUMMARY

The shown optimization systems have a significant impact on the energy efficiency and reduced emissions. The efficiency enhancements can either assigned

- directly to the plant or may materialize
- in subsequent plants caused by a higher product quality or an increased productivity.

Not only the direct savings are noteworthy, the indirect savings in subsequent plants are considerable, too.

Proven by plenty successful references, Siemens VAI offers a number of advanced automation systems which successfully support energy efficient plant operation.