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# Latest Generation Sinter Process Optimization Systems

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## 1. Introduction

SIMETAL Sinter VAiron is an advanced process optimization system which covers the sinter production process from ore preparation in the blending yards and sinter plant up to the blast furnace. It was developed in a close cooperation between the Austrian steel producer voestalpine Stahl and the engineering and plant-building company Siemens VAI. The overall target of this system is to achieve stable process conditions at a high productivity level with a uniform sinter quality at low production costs. This is achieved through the application of a number of sophisticated tracking, diagnosis and control models and systems which are bundled within an overall expert system.

## 2. System objectives

In the sintering process, chemical and physical parameters such as basicity and product diameters must satisfy pre-set target values within defined standard deviations in order to meet the quality requirements of the blast furnace. Sinter quality begins with the selection and mixing of the raw materials in the blending yard and dosing plant which are integrated in a common control model of the Sinter Process. The chemical properties are homogenized 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 the system. The system has to counteract changes caused by fluctuations, which is achieved by a closed-loop control of the process.

The main targets of the SIMETAL Sinter VAiron[1] process control system are summarized as follows:

- Minimizing fuel consumption – The fuel rate is a key factor in production costs.
- Avoidance of heavy control actions – If only minor control actions are necessary, the sinter machine performance is stabilized significantly.
- Avoidance of critical process situations – The sooner the system reacts to critical process situations, such as an inhomogeneous mixture, poor surface ignition or incomplete burn-through of mix, the smoother the overall sintering process is, resulting in a more uniform product quality.

[1]Later on in this document we will briefly call the system '*VAiron Sinter*'.

- Synoptical operational decisions throughout all shifts – Constant operating conditions throughout all shifts will increase the lifetime of the equipment and reduce production costs.
- Reduction of emissions – With the closed-loop operation mode of the VAiron Sinter Expert System, the production parameters can be optimized within the environmental emission limits, in particular, $SO_2$ emissions.

## 3. System structure and technological controls

A reliable and well proven basis automation system is the backbone of modern sinter plant operation. VAiron Sinter is characterized by a modular system structure (Fig. 1).

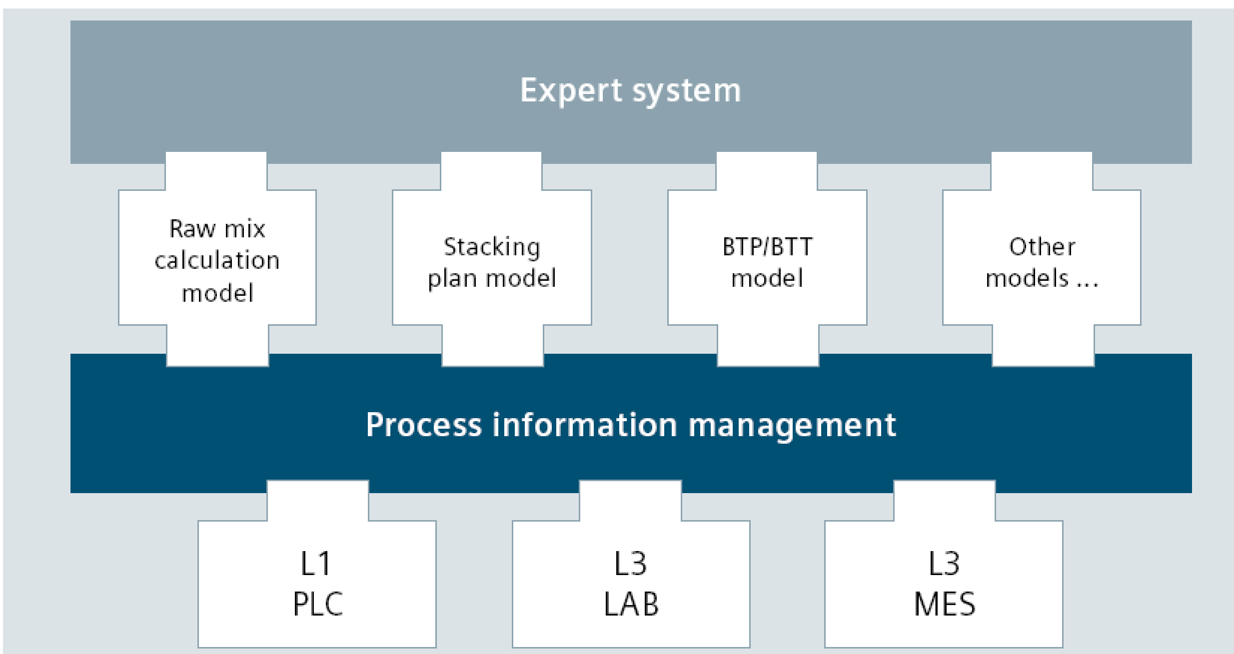


Fig. 1. System Structure.

In addition to basic functions such as data acquisition and set-point execution, the technological controls (main control loops) are implemented in the basis automation system. These include raw-mix-ratio control, raw-mix-feed control, moisture control, surge-hopper-level control, drum-feeder control, ignition-hood control, exhaust-gas-cooler control and cooler control. The focus of these basic control functions is to assure a smooth and reliable sintering process and to enable a continued process optimization.

### 3.1 VAironment – Process information and data-management system

A multithreaded, three-tier, client-server real-time application is the basis for the hardware and software configuration in VAiron Sinter. The data acquisition function pre-processes the data from a broad spectrum of raw data sources (front-end signals, material weights, laboratory data, events, model results and cost data, etc.) before storing these in the plant database (Fig. 2).

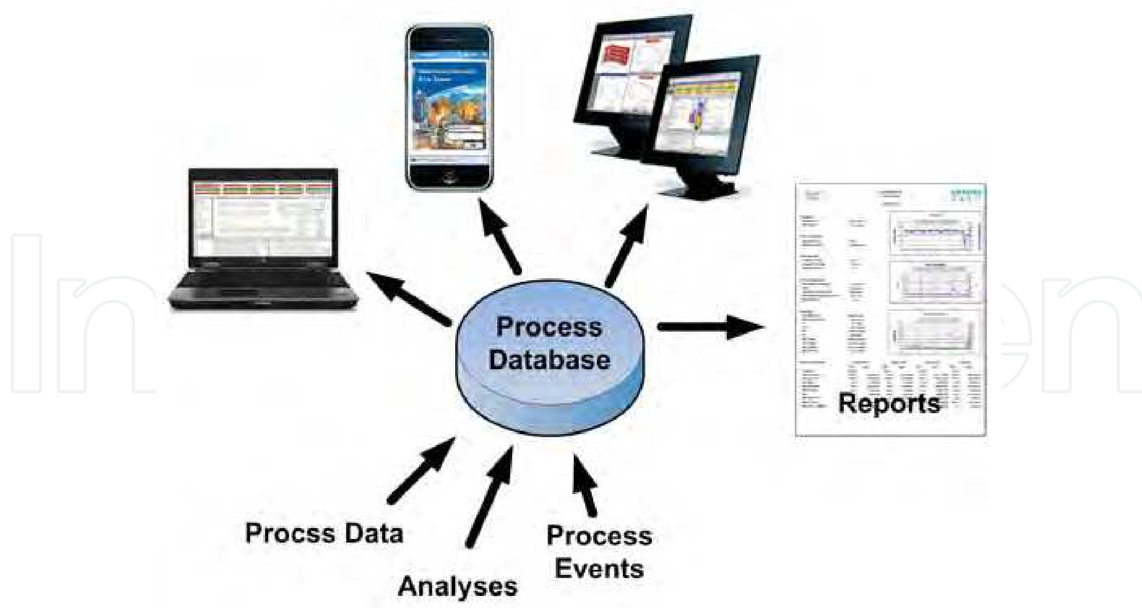


Fig. 2. VAironment Process Information and Data Management System.

The process information management system provides a flexible and powerful database for the continuous improvement of process knowledge. VAiron Sinter interprets process data, performs model calculations and visualizes the results in Windows- or web-based graphical user interfaces. Additional data analysis, interpretation and visualization tools can connect to VAiron easily (COM, ODBC). The module-based system is highly configurable in order to allow for adaptations related to modifications in the plant setup or operational philosophy.

Data handling encompasses the chemical and physical data of the sinter strand as well as the process history. The raw sinter mix and the production process is monitored in detail from ore preparation to the blast furnace. Unfavorable conditions can be detected and eliminated (**Fig. 3**).

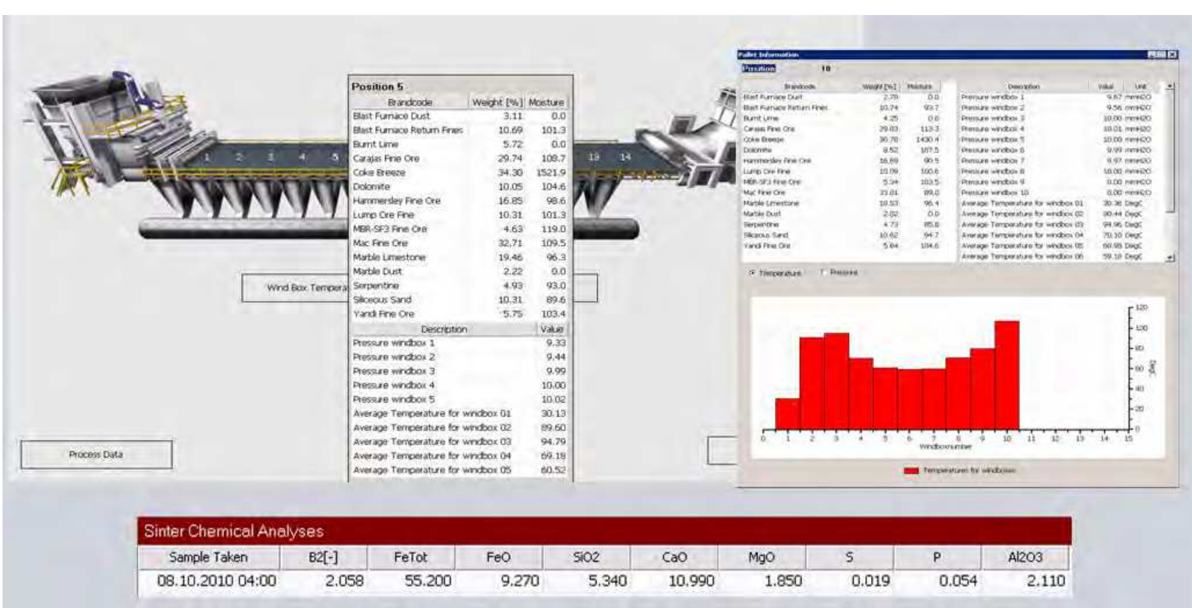


Fig. 3. Detailed Tracking of Material Packages.

### 3.2 VAiron process models

A number of process models are available in the VAiron Sinter automation package as outlined in the following.

#### 3.2.1 Raw mix calculation model

Producing target quality requires accurate charging of the raw materials (ores, coke, additives, etc.). To modify the raw mix recipe, the coke addition, sinter basicity, raw material analyses and their influence on sinter parameters must be taken into consideration. This procedure is complex and requires computer assistance.

The purpose of the raw mix calculation model is to establish a raw mix composition, in order to automatically achieve the assigned target values for coke addition, sinter basicity, $Fe_{tot}$, $SiO_2$, etc.

Up to four variable materials may be chosen – one for the basicity equation, one for $Fe_{tot}$ balance, and one for $SiO_2$ balance as well as one for the MgO balance.

The results of the raw mix calculation can be activated manually to run on Level 1.

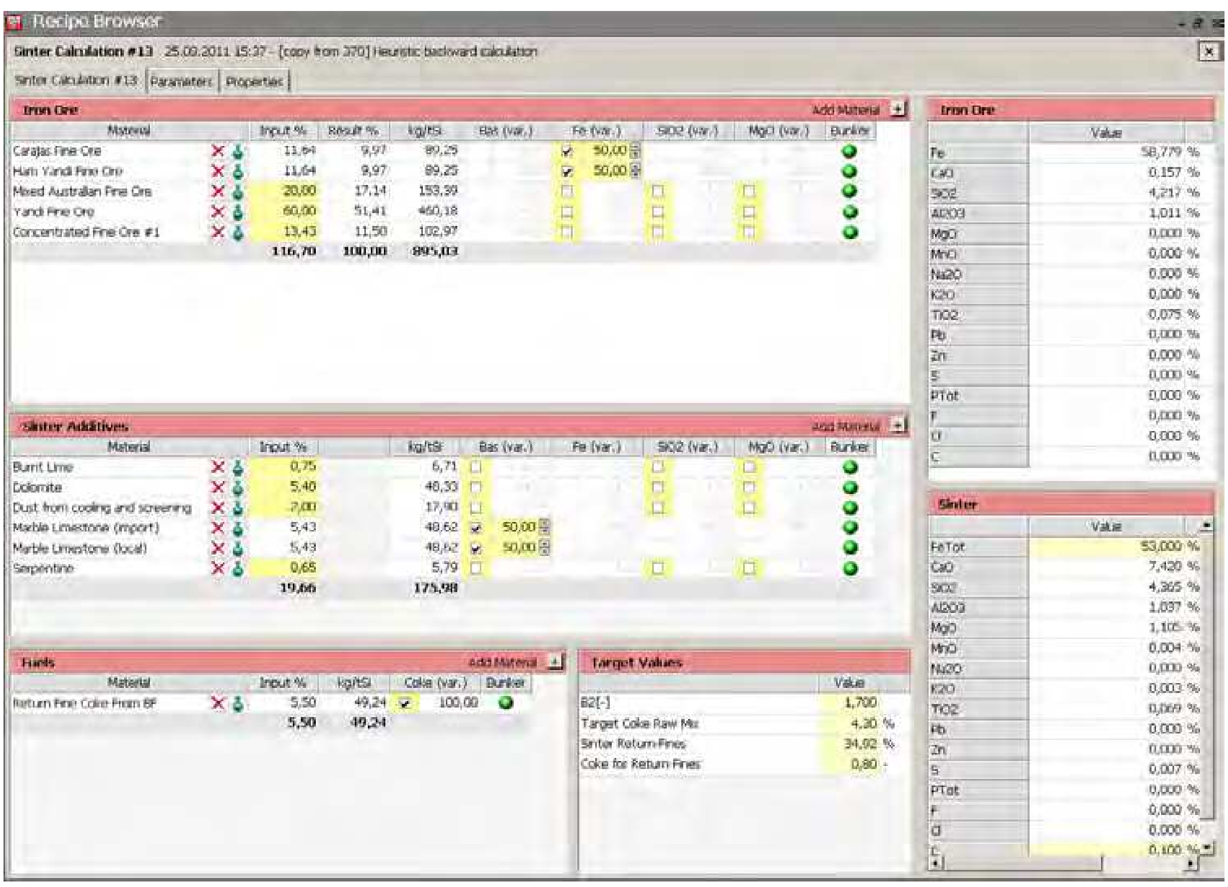


Fig. 4. Raw Mix Calculation for Sinter Plant.

In combination with the Expert System, the raw mix calculation model is a central part of the closed-loop operation, which is a unique highlight of the VAiron Sinter automation solution. A screen of the user interface of the raw mix calculation model is shown in Fig. 4.

#### 3.2.1.1 Calculation of material ratios (backward calculation)

The aim of this calculation mode is to calculate the set-points for the raw material system (material ratios) in order to reach the chemical sinter composition with the desired results.

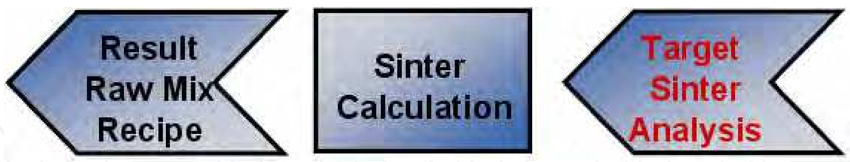


Fig. 5. Backward Calculation Procedure.

Several calculation options are available:

- To aim at a certain basicity
- To aim at a certain $Fe_{tot}$
- To aim at a certain $SiO_2$
- To aim at a certain MgO
- Calculation of the set-point for fuel materials

The advantage of the backward calculation (Fig. 5) is to reach and keep the product quality as stable as possible and optimize the material costs.

#### 3.2.1.2 Calculation of sinter composition (forward calculation)

The target of this calculation is the opposite of the calculation of the raw material ratios, i.e. to calculate the chemical analysis of sinter using the composition of the raw materials as an input.

Using this calculation option, the model calculates the theoretic chemical composition of the sinter product based on fixed material ratios input by process engineers or operators.

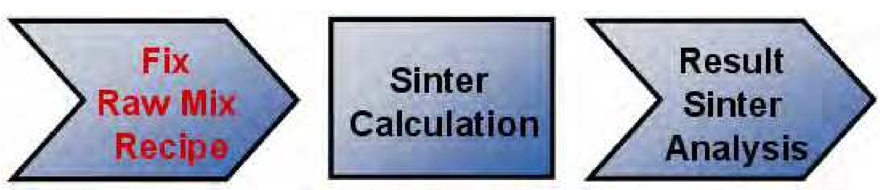


Fig. 6. Forward Calculation Procedure.

#### 3.2.1.3 Online calculation of sinter composition (forward calculation)

This calculation is identical to the previously described calculation of the sinter composition with the difference that the actual charged material ratios from Level 1 are used as input for the calculation. Therefore, the model is started automatically in the background when a new Level 1 recipe is detected and it calculates the actual sinter composition using the actual raw mix data.

### 3.2.2 Stacking plan for blending ore bed

The model calculates a stacking plan for blending ore beds based on the raw mix composition calculated by the corresponding raw mix calculation. After considering the availability of materials and intermediate bunkers, the stacking process is organized in several stages. The model calculates the material flow rate during stacking so that a homogeneous blending ore bed with constant chemical properties is achieved. The stacking process is monitored and deviations from the plan are compensated automatically. A screen of the stack plan model for the blending ore bed user interface is shown in Fig. 7.

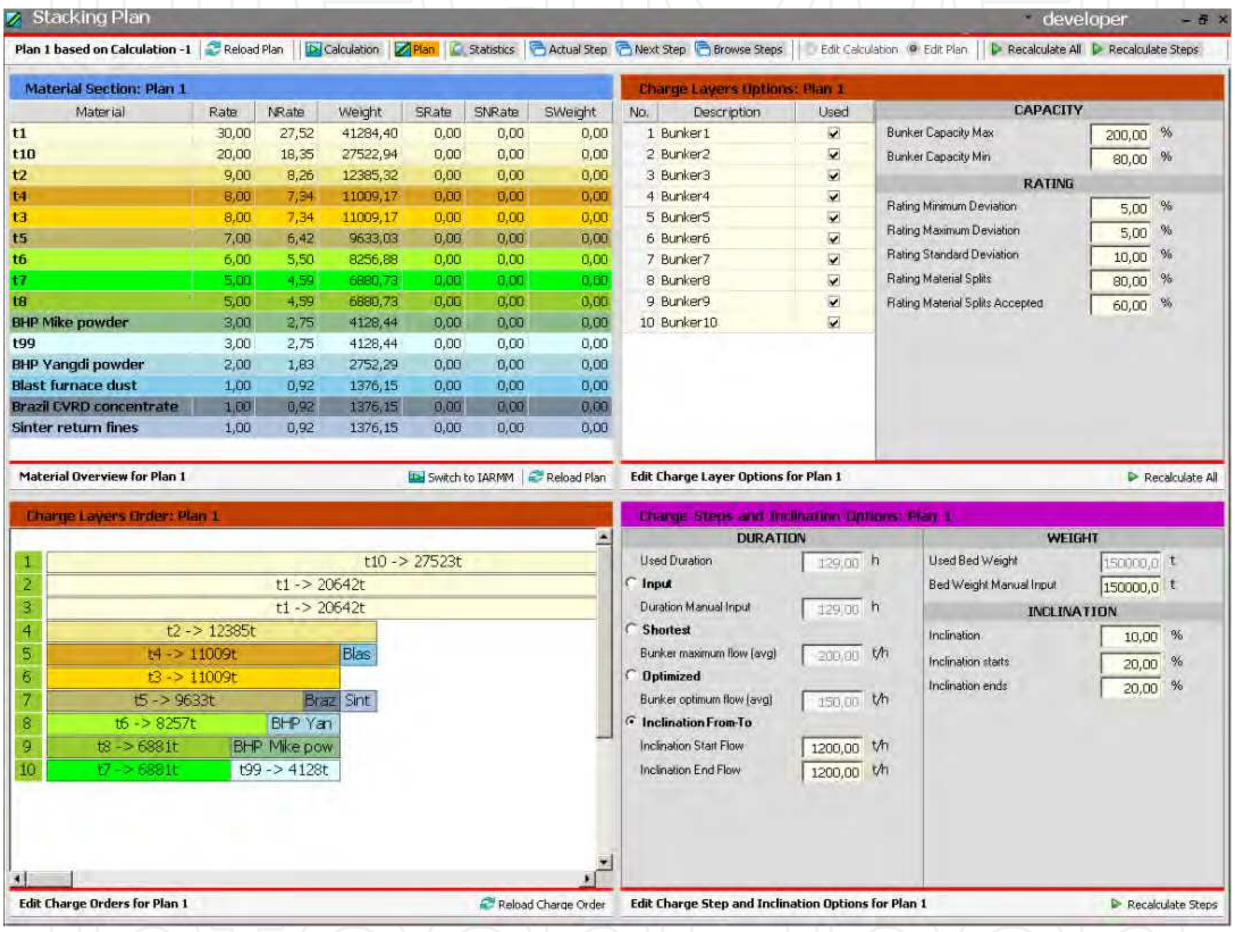


Fig. 7. Stacking Plan User Interface.

### 3.2.3 Blending ore bed distribution model

This model simulates the 3D geometry of the blending ore bed by calculating the volume of the material mixture per stacking step. For this calculation, the bulk densities and the angles of repose for each material type are required (Fig. 8). Furthermore, the spatial distribution of analysis data such as Fe and S are calculated. In the offline mode, the model calculates the geometry of the bed based on the stacking plan. In the online mode, the model builds up the bed using actual material data, the exact position of the charging device, the brands of the materials and the material quantities.

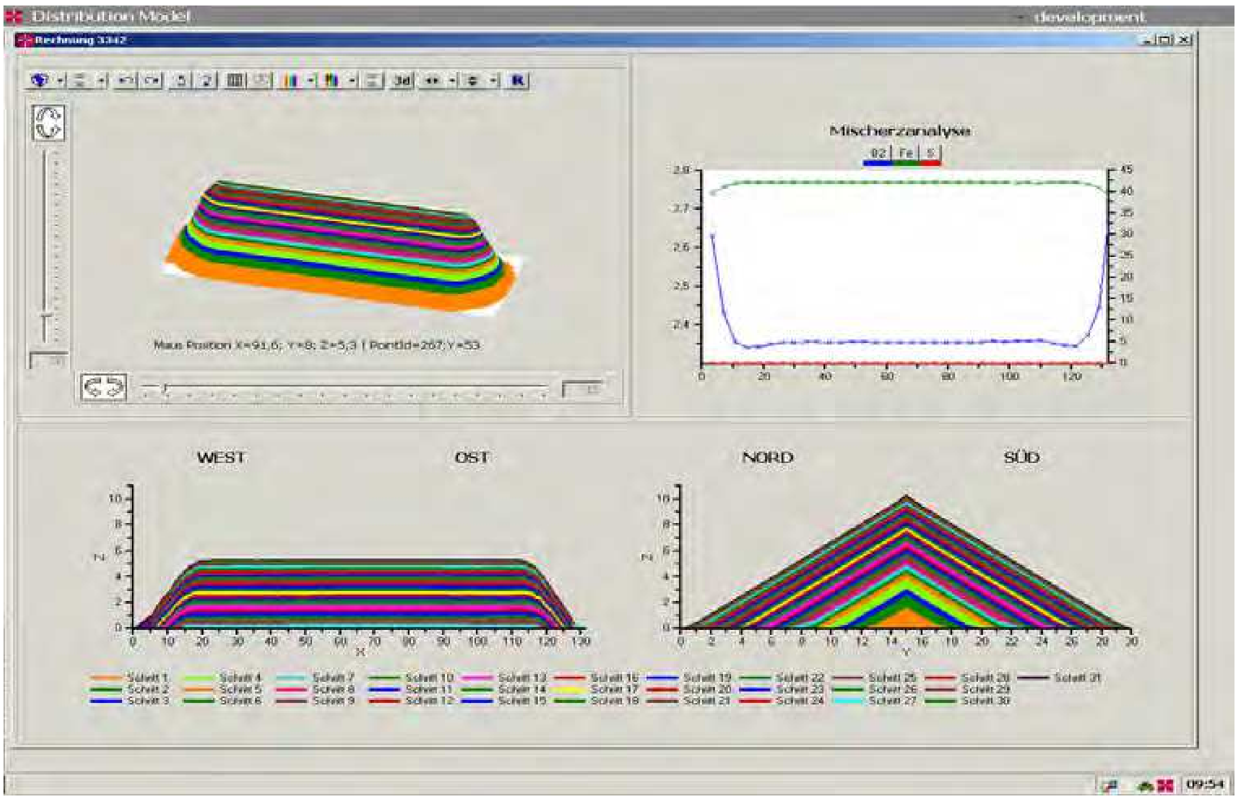


Fig. 8. Visualization of Ore Blending Bed Distribution Model.

### 3.2.4 Sinter process supervision models

In addition to the complex process models that are subsequently described, many auxiliary calculations are performed. These calculations include filters for suppressing short-term fluctuations. Examples are:

- Raw mix permeability is derived from ignition hood data, taking into account the pressure drop, bed height and waste-gas flow under the ignition hood
- Moisture calculation of the raw mix
- Average particle size of the raw materials
- The harmonic diameter of the sinter product (calculated from the grain-size distribution of the sinter analysis) as an important indicator of sinter quality[2]
- The actual burn-through point position which has a major influence on the control of the sinter strand velocity

A total of approximately 700 different model values are calculated.

[2]A particle size distribution with mass fractions $x_1$, $x_2$, $x_3$, … $x_n$ corresponding to maximum diameters (measured as screen size) $d_1$, $d_2$, … $d_n$ has a harmonic diameter $D_h := 1 / \sum (x_i/d_i)$. The harmonic diameter is a good indicator of the permeability of the material (i.e., sinter in the blast furnace). A low fraction of material with small diameters leads to high $D_h$ and thus to good permeability.

### 3.2.5 Burn-through time prediction model

The model predicts the dynamic behaviour of the sintering based on the process conditions and raw mix parameters, including permeability and waste-gas data. The predicted burn-through time is used as an important input parameter for the advanced control strategy of the Sinter VAiron burn-through point controller.

### 3.2.6 Productivity analysis tool

VAironment allows for the long-term archiving of recipes, chemical and physical analyses and all kinds of measured process data. This comprehensive data archive allows for the retrospective analysis of best process conditions for specific raw materials. The productivity analysis tool supports highly sophisticated search strategies in finding optimal process parameters for a given raw material according to different objectives, such as a maximal productivity and minimal fuel consumption.

### 3.2.7 Sinter process model

The top layer of the raw mix is ignited in the ignition hood. After the sinter mix leaves the ignition hood, combustion continues by drawing air through the bed which progresses downwards through the entire bed. When the combustion reaches the bottom layer of the sinter mix, the entire bed has been sintered. This point is called the sintering point or burn-through point (BTP).

Proper control of the sinter strand speed aims at positioning the BTP close to the end of the strand. If the BTP is situated before that ideal position, the area after the BTP is only used for cooling the sinter. This leads to a diminution of the active sintering area and a productivity decrease. If it is not reached within the sinter strand, un-sintered sinter mix is discharged and has to be recycled as return fines – leading to a productivity decrease. Furthermore, this results in poor sinter quality. The position of the BTP is measured by thermocouples installed in the last suction boxes and is characterized by the maximum value of the exhaust gas temperature detected by the thermocouples within these suction boxes.

A paramount control goal in the sintering process is that the material must be completely sintered by the time it reaches the end of the sinter strand (minimized return fines) and that the BTP is as close as possible to the ideal position for maximum productivity.

The gas flow through the sinter strand is a function of the permeability of the raw mix. As the total sintering time depends on the total gas flow, a higher permeability will obviously lead to shorter burn-through times. However, it is also clear that a higher gas flow through one section of the sinter strand will slightly reduce the gas flow through the material in other zones along the sinter strand. Taking this into consideration, a permeability-based simulation of the sintering process can thus be applied for an improved sinter-process control to achieve higher productivity. This solution approach was implemented in the sinter plant control system.

For example, the pronounced rise in the BTP curve beginning at time interval 43 of Fig. 9 is a consequence of an increased permeability of the raw mix at this position. The temporary BTP drop immediately preceding this rise is a result of the reduced gas flow through the raw mix, as explained above. As soon as the permeability falls, the BTP curve also drops accordingly (time interval 54). The inexact response correlation between the flat trend of the permeability curve and the irregular trend of the BTP can be explained as being the result of the accumulated nonlinear effects of varying gas flows through different sections of the sinter strand on the BTP. On the right-hand side of the diagram (time intervals 80 to 113), the inverse situation for a reduced permeability is shown.

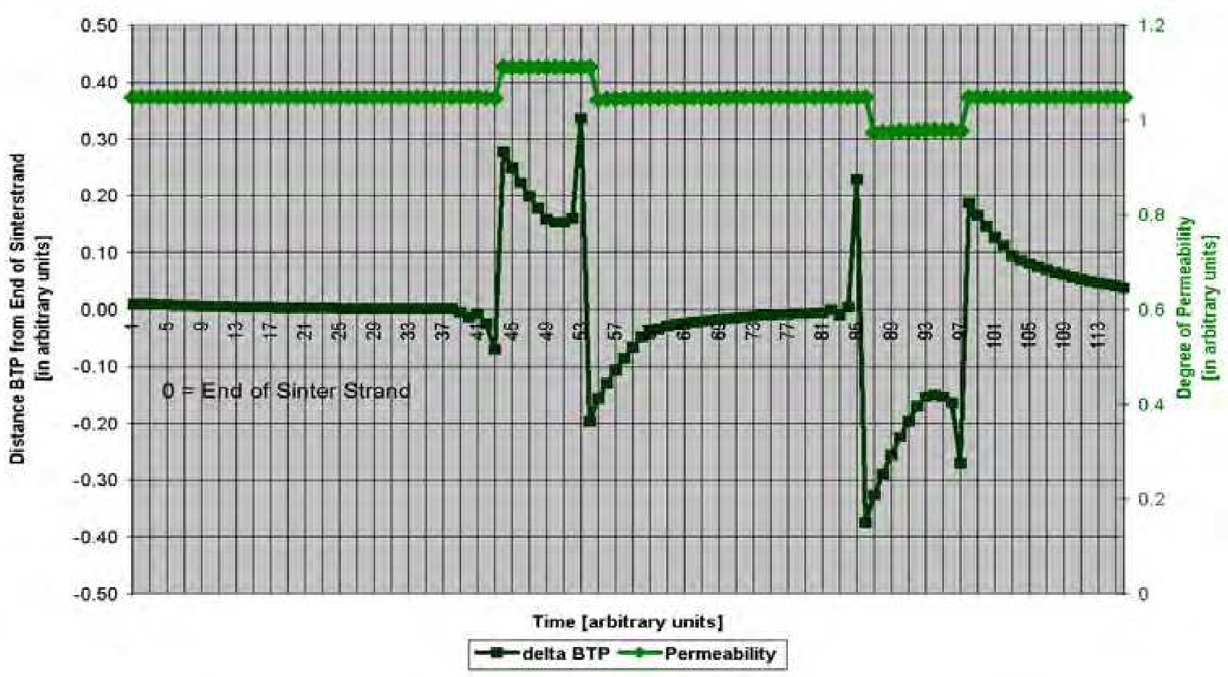


Fig. 9. Illustration of Simulated Dependency Between Permeability of Raw Mix and Distance of BTP from End of Sinter Strand; Plotted as Function Of Time (measured in arbitrary units).

If the sinter is not completely burned through before reaching the end of the strand, a decrease of the sinter strand speed is the logical control action. Choosing the proper speed reduction for the sinter at the end of the strand will result in an increased duration of the material spent at the beginning of the strand that is longer than ideal. This sinter will be burned through before reaching the end of the sinter strand, again necessitating an increase in the strand speed. This, in turn, means that the BTP of the following material will again be too close to the end of the sinter strand. For conventional automation solutions, e.g., PID (Proportional Integral Differential)-based control, this effect tends to lead to BTP and thus strand-speed oscillations when trying to compensate for the fluctuations. The sintering process model predicts the Burn-Through Time (BTT) as an indicator for the dynamic behavior of sintering, based on the process conditions and raw mix parameters, e.g., the material permeability. The compiled prediction of the BTT for discrete sinter strand segments is one of the important starting points for the calculation of the optimum sinter-strand speed by the Expert System.

### 3.3 VAiron sinter expert system

One of the most important factors for the control of the sinter process is to make operation of the sinter plant as smooth and steady as possible. The process can be disturbed, however, by changes in the properties of charged materials, failures in the process, human factors, process conditions, etc. Delays in corrective measures compensating for the interference factors may vary from minutes to hours, days and weeks. Correct timing of control actions and anticipation of disturbances is of utmost importance for maintaining high production rates and low production costs.

The knowledge of experienced sinter process engineers and operators on the process, the cause and effect relationships of process disturbances, metallurgical know-how, and the adopted control philosophy is modeled into the expert system. It monitors and forecasts the process status, gives alarms in case of process disturbances, suggests control measures, and describes the changes in the process in the form of verbal messages and graphical displays. With the help of the experts system, the expertise of the process control personnel is improved, the process control practice among the different shifts becomes more uniform, and, on the basis of forecasting, the operation of the process becomes smoother as compared to conventional process control. Monitoring of measurement data and indices based on those measurements becomes more efficient with the help of the expert system.

Therefore the sinter expert system has two main objectives. The first is the situation analysis of the phenomena called *diagnosis* and the second is the *therapy* in which proposals are presented to the process control personnel in order to achieve and keep stable conditions.

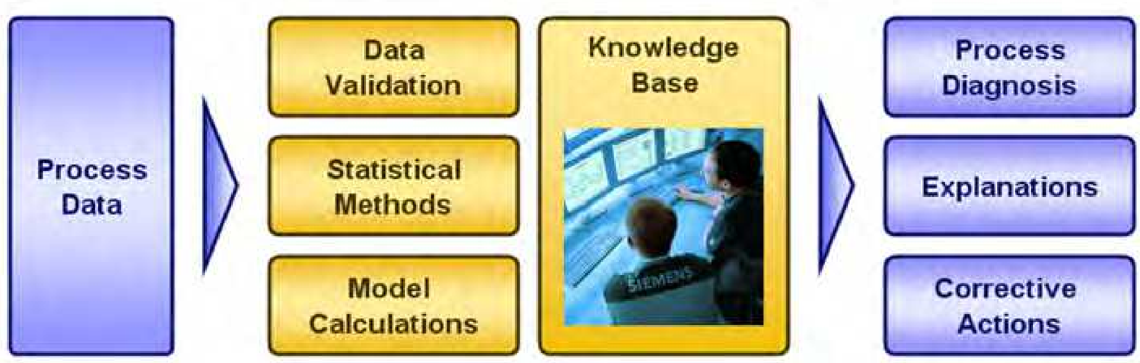


Fig. 10. Structure of VAiron Expert System.

The sinter expert system studies the occurrences of the phenomena around the sinter process by means of various technical calculations and makes conclusions based on those calculations. The calculations are based on results from process measurements.

The basic structure is shown in Fig. 10. The system diagnoses the overall sinter plant status and previous sintering conditions. The tasks and functions of the expert system are outlined in the following sections.

#### 3.3.1 Life-phases of the expert system

At delivery time the system is prepared according to the rules defined by process experts of Siemens VAI and the customer. Experience gathered during the commissioning phase (with real time process data) will help to fine-tune the system. The expert system has to be maintained and enhanced during operation by the customer's personnel after take over. Thus the life-time of the expert system may be separated into three distinct phases:

| Phase | Responsible | Description |
|---|---|---|
| Development of base system (based on Siemens VAI's experience and customer's know-how) | SVAI | Implementation of diagnosis structure, implementation of described diagnoses and actions, implementation of explanation capability, implementation of interfaces |
| Fine-tuning during commissioning (based on operational data) | SVAI / Customer | Fine-tuning of described diagnoses and actions |
| Maintenance and further enhancements (based on operational data) | Customer | Further adaptations, reaction on equipment changes, implementation of new diagnoses and/or actions |

Table 1. Life-phases of the expert system.

Modifications of the expert system can be done by the customer's personnel according to the following topics:

- Fine-tuning of delivered diagnoses and rules - As described above the expert system has to be maintained throughout its lifetime. The simplest form of maintenance is fine tuning of the delivered application, i.e. modifications of existing but no addition of new parts. Customer's personnel may change tuning parameters stored outside the expert system.
- Addition of other diagnoses - If the expert system shall increase its diagnosing capability, one has to add new diagnoses.
- Addition of other therapies - If new suggestions of corrective actions shall be provided by the expert system, one has to add new rules.

The VAiron Sinter expert system includes a Metallurgical Model Toolbox and its own scripting language. This toolbox enables the modification of the logics of existing diagnosis and rules and the creation of new diagnosis and rules based on the specific requirements of operation.

### 3.3.2 Sinter plant control HMI – Expert system

Various process model results, control trends as well as the diagnoses are visualized in this HMI. It offers the following functionality:

- Checking of the performance of the various models using dedicated screens, i.e. tab folders in the Sinter Plant Control HMI.
- Modification of parameters for the individual models.
- Switching between closed-loop and semi-automatic mode for the individual controls.

The expert system HMI looks as follows:

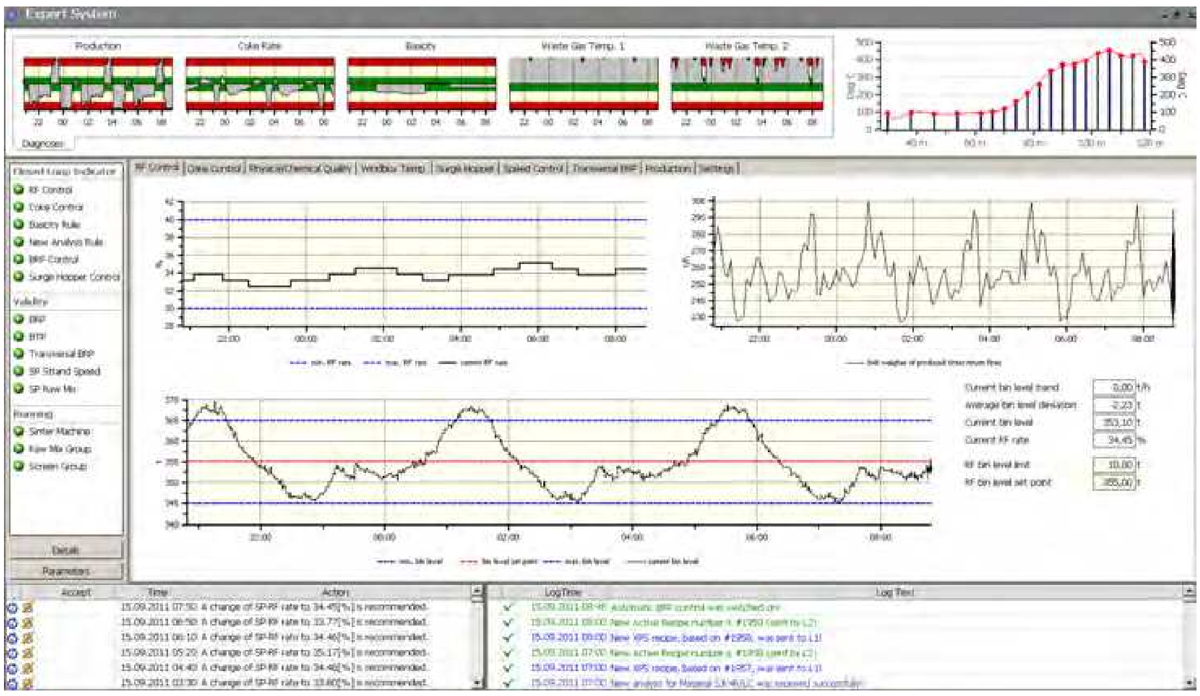


Fig. 11. Sinter Expert System HMI.

### 3.3.3 Diagnoses

The expert system studies the occurrence of phenomena in the sinter process using a variety of technical calculations and it draws conclusions derived from them. The calculations are based on a large amount of process measurement and analyses data that is collected continuously.

The following standard diagnoses are provided by the expert system:

| Diagnosis | Description |
|---|---|
| Production | A moving average of the sinter production over a certain period of time (e.g. 1 hour) compared to the target sinter production. |
| Fuel Consumption | Moving average of the fuel consumption over a dedicated period of time (e.g. 1 hour) compared to target fuel consumption. |
| Chemical Quality | The basicity of the last received chemical sinter analysis is compared to the target basicity value. |
| Physical Quality | The harmonic diameter of the last received physical analysis is compared to the target value. |
| Environment | A moving average of the components of the waste gas analysis over a certain period of time (e.g. 1 hour) is compared to their target values. |
| Waste Gas Temperature | Moving average of temperature measurements in the main duct before the E.P. over a certain time period (e.g. 1/2 hours) is compared to the target value. |

Table 2. Provided Expert System diagnoses.

### 3.3.4 Therapy

The expert system provides the following two types of user notifications regarding the therapy to achieve and keep a stable and smooth sinter process:

- Plausibility checks on measurements
- Corrective actions

#### 3.3.4.1 Plausibility checks on measurements

A check action is created and presented to the user for all process variables that were found to be initially missing or invalid.

No further checks on the equipment are provided. This means that there are no further examinations, whether the measuring device is really faulty or not.

The check actions are given in textual form like

- The temperature of thermocouple in wind box #13 is unusual and therefore suspicious
- The analysis deviation (100%-∑elements) of the Sinter analysis exceeds 10%. Please check the analysis.

#### 3.3.4.2 Corrective actions

Corrective actions are proposals for the operating personnel to change some process parameters (set-points). The expert system suggests at the same time one or more corrective actions out of a set of possible ones. Some of the corrective actions are provided qualitatively, that means the expert system suggests increasing or decreasing something instead of giving exact values to the user. Others are provided quantitatively, that means the new set-point is provided by the expert system.

Internally, the process of suggesting a corrective action is functionally divided into three groups based on the respective objectives as shown below:

- Situation Analysis (to judge the kind of process variations that have occurred)
- Phenomenon Recognition (to judge the kind of phenomenon expressed by that variation)
- Action Determination (to judge the action against the phenomenon)

Selected corrective actions have to be acknowledged by the operators. This is especially necessary if the expert system is in semi-automatic mode. The operators can enter a reason if they do not follow the expert system's suggestions and this action is suppressed until its status changes. This gives important information for tuning of the expert system.

The action execution can be separated into two operation modes which can be set for each rule and control individually as follows:

- Semi-Automatic Mode
- Closed-Loop Mode

The current operation mode for each rule/control is displayed in the expert system HMI (section) and indicated by green and red lights (see Fig. 11). The distinction between semi-automatic and closed-loop mode is described in detail in the section below.

**Semi-automatic mode**

If a rule or control is in semi-automatic mode, a detailed description of all recommended changes is provided to the operator by the expert system. During a configurable period of time (usually 10 – 15 minutes) the operator has the possibility to accept or decline the suggestion.

In case of rejecting the suggestion no further action will be executed. Additionally an input field is provided to key in a reason for refusing this suggestion.

If the operator has the opinion that the suggested set-point/recipe change is necessary to keep smooth process conditions, he has the possibility to accept the change. Afterwards the expert system is executing the changes and sends the new set-points/raw mix recipe to the Level 1 system automatically.

In case of neither rejecting nor accepting the recommended set-point/recipe change during the configurable period of time, the expert system will automatically reject the recommendation and no further actions will be executed as well.

**Closed loop mode**

For the recommendations of rules and controls switched to Level 2 closed loop mode a detailed description of necessary changes is provided as well. The pending time, in which the operator can accept or decline this suggestion, is also configurable (usually 5 – 10 minutes).

The only significant difference to the semi-automatic mode is the behavior after expiration of the configurable period of time without an operator action. In the closed loop case, contrary to the semi-automatic mode, the expert system will automatically accept the recommended changes and sends the new set-points/recipe to the Level 1 system.

**3.3.4.3 Controls**

Controls are actions that are executed continuously (e.g. every minute) for fast reactions to keep the process stable and usually run silently in the background. They are typically switched on or off on Level 1. Controls may also use a validity flag indicating its state to Level 1.

The controls shown in the following table are typically included in the expert system.

| Corrective Action | Description |
|---|---|
| Change position of feeder gates | To ensure a homogeneous flame front in the transverse direction of the sinter strand, the transversal burn-through deviation control adjusts the packing degree. This leads to a constant burn-through of the sinter in transverse direction. The advantages for the sinter process are fewer and more stable sinter return fines. |
| Change sinter machine strand speed | The burn-through-point control maintains a target of the burn-through-position. This is achieved by modifying the speed of the sinter strand in accordance with the preset burn-through point position. The effect of this control leads to a maximized possible production of the used raw mix composition. |

Table 3. Expert System Controls.

#### 3.3.4.4 Rules

Rules are actions that are suggested at specific events (e.g. new sinter analysis) or they are triggered periodically. Since rules are slower controls or major changes in plant operation, a rule is always explained textually. So an operator can decide if he wants to follow the rule or not. In case of switching a rule to closed loop mode, it will be processed automatically after a certain period of time if the operator does not reject the suggestion with the expert system user interface.

The rules shown in the following table are evaluated by the expert system.

| Corrective Action | Description |
|---|---|
| Change Basicity | Sinter properties represented by chemical parameters such as the basicity (CaO/SiO2) have to be kept within an acceptable deviation from the preset target values. This control loop adjusts the raw mix composition in order to maintain the target values. |
| Re-Calculate current Recipe | In case of a new chemical analysis received from the laboratory for a material which is currently used in the active recipe, a new sinter calculation is performed. |
| Change sinter return fines | A harmonized sinter plant return fine bin level over a long term is the objective of the return fine control. The return fine consumption in the raw mix composition is adjusted to keep the return fine bin level within a range. |
| Change Coke for raw mix | In order to keep the FeO content of the sinter within an acceptable range, the coke control stabilizes the sinter return fine balance. Therefore, the control modifies the coke consumption in the raw mix composition in accordance with the sinter return fine balance. |

Table 4. Expert System Rules.

### 3.3.5 Sinter plant productivity control

A very important part of the expert system represent the two controls described in section 3.3.4.3, namely the *Burn-Through-Point* and the *Transversal Burn-Through-Point Controller*. These controls improve the overall plant productivity.

There are many indicators for the strand-speed control with different precision. Some of these are available at an early stage in the process (e.g. the permeability), others only with long time delays after the process on the strand has been finished (e.g. the harmonic diameter). Generally, the information attained at a later stage is more precise than that attained early on.

The fundamental idea was therefore to use the early information to control the processes and to use the information that is attained at a later stage to self-tune the control system. With these two independent sources of information it is possible to achieve high control accuracy despite fast corrective actions. A general overview of the main parameters that affect productivity control is shown in Fig. 12. Since the availability and reliability of the listed data differs from plant to plant, the expert system can be based on individually selected entry data of the respective plant.

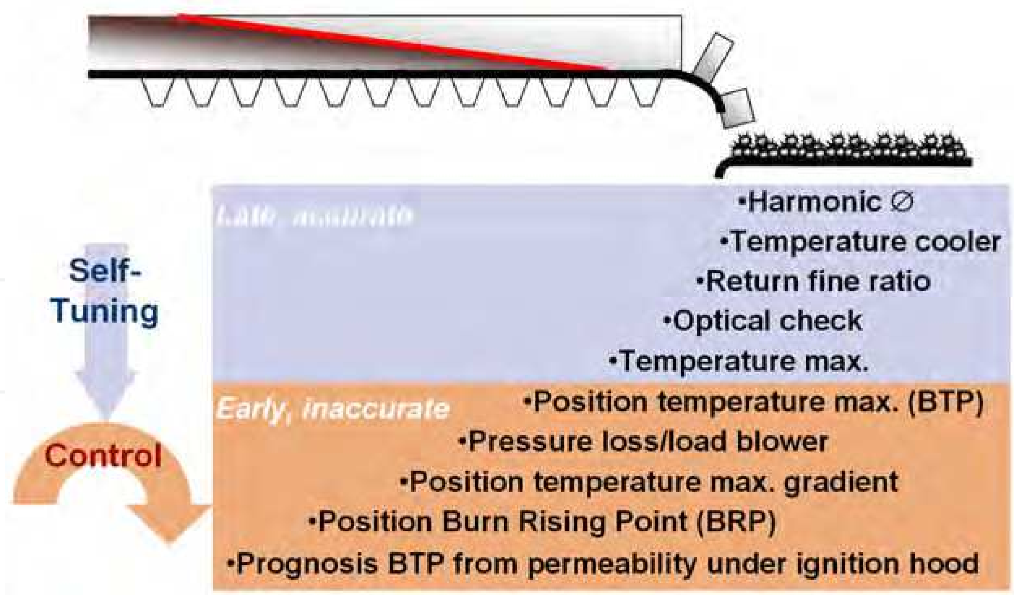


Fig. 12. Overview of Sinter Plant Productivity Control.

In the longitudinal BTP optimization described above, the objective is to obtain an average BTP position that is optimally distanced from the strand end. Full utilization of the surface of the sinter strand, however, can only be achieved when, at the same time, the flame front also reaches the lowest layer across the entire width of the strand (in a transversal direction). This is obtained through the transverse burn-through point control (Fig. 13). Here, feedback on the burn-through point is derived from the temperature conditions in a transverse direction from the last suction boxes and corrective measures are then executed online directly through proper adjustment of the angle of flaps near the drum feeder. In this manner, a uniform flame front can be achieved.

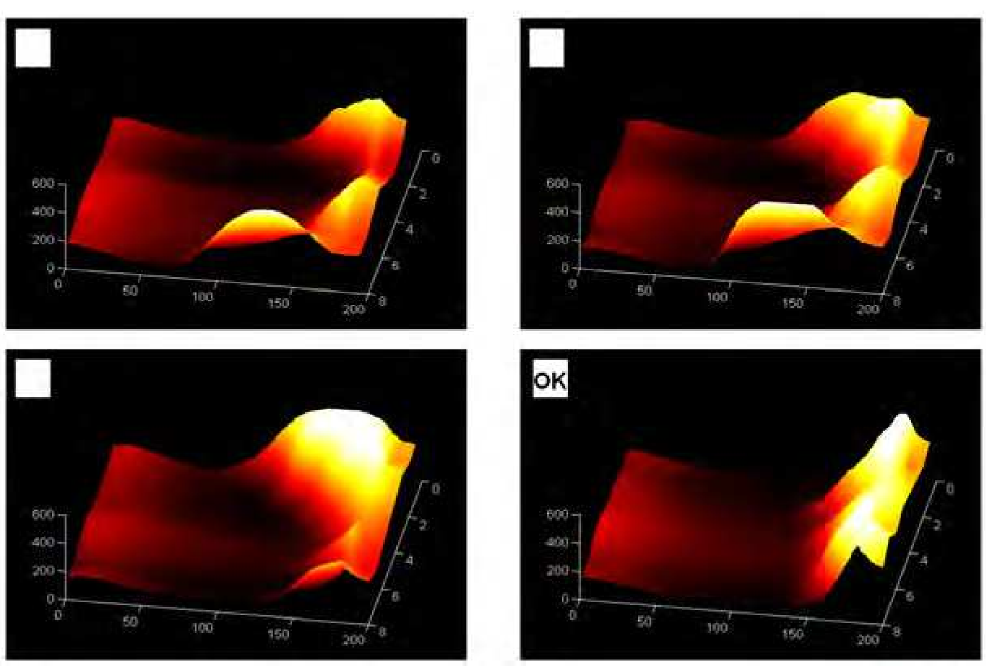


Fig. 13. Transverse Burn-Through Point Control

## 4. Savings and benefits

### 4.1 Advanced data management

From a broad spectrum of raw data sources, the data acquisition function pre-processes the plant data before storing it in the plant database. This database is of key importance to the advanced process optimization. The following data are collected from the process and connected systems:

- Continuously measured process data from the Level 1 system
- Amount of material charged
- Plant status data (runtime, shut-down, special process situations, etc.)
- Chemical and/or physical laboratory analyses data of all raw-materials and sinter
- Active raw mix recipes

Additionally, applications to visualize the above mentioned collected data are provided:

- Tag-Visualization program for graphical representation of any kind of time-based data in the database
- Lab-Browser application for material analyses visualization and evaluation
- Reporting system allowing for cyclical (e.g. daily) or on-demand report generation

The system can serve as a link between different automation levels in the customer's company: it is connected to the aggregate's Level 1 automation and it can be connected to the plant wide network. Therefore it can send production and consumption data as well as important process data to a Level 3 system.

### 4.2 Increase of operator know how

The expert system generates textual explanations for its diagnoses and suggestions. In combination with the graphical information provided by the system (see Section 3.3.2), the operator can understand the actual situation of the plant in detail. Using these facilities, the operator can permanently learn about the process and background of the knowledge system. In consequence, the system will improve the skills of the operational personnel.

### 4.3 Smooth plant operation

The expert system checks a number of process state indicators in a typical time cycle of five minutes:

- Several hundred measurement points from the Level-1 automation, and
- Related model calculations for internal process states which cannot be measured directly

Deviations from optimal process conditions can therefore be detected early. Small counter actions are sufficient to correct the process conditions at this early stage. Even experienced human operators are unable to cope with this flood of information and will detect such deviations later than the expert system.

In consequence, the main difference between manual operation and operation supported by the expert system is that the latter is characterized by more frequent, but smaller control actions. The resulting smooth operation of the sinter plant leads to:

- Higher availability of the sinter plant
- Longer overall lifetime of the sinter plant
- Reduced maintenance efforts and costs

### 4.4 Uniform operational philosophy

The VAiron expert system is customized for each individual plant where it is installed. In a first phase, the customer specific situation regarding raw materials, plant topology, equipment, etc. is analyzed. The specific rules are developed in cooperation between Siemens VAI specialists and experienced process engineers and operators of the customer. Specific customer operational philosophy is implemented instead of standard rules as a result of this cooperation during the engineering phase. During system commissioning the rules are fine-tuned together with the customer.

This approach has the following advantages:

- High acceptance of the system, because it reflects the internal operational philosophy
- The customer's operational philosophy of the most experienced personnel is followed 24 hours a day, 7 days a week
- Consistent sinter plant operation over all shifts, resulting again in smoother plant operation

### 4.5 Increased sinter plant productivity

The use of the Burn-Through-Point controller typically leads to an increase in the sinter plant productivity between 2% and 5%. An additional increase can be achieved if the flame front is uniformed along the full width of the sinter strand by means of the Transversal Burn-Through-Point Controller.

The usage of a higher percentage of sinter with stable quality in the blast furnace burden results in a further reduction of the blast furnace fuel consumption. Therefore, the increase of productivity of the sinter plant is a very important benefit of the expert system.

### 4.6 Reduced fuel consumption and stabilized sinter quality

The expert system ensures an economic fuel usage by keeping the return fines ratio at the optimal level. Whenever the average production of internal return fines deviates from the optimal value, the expert system corrects the process conditions (mainly the fuel addition) in order to compensate the deviation. Reduced fuel consumption and increased productivity are achieved by this control loop.

Stabilization of sinter quality is achieved by dedicated quality controllers considering incoming sinter analyses from laboratory and performing corrections of the raw mix recipe, if deviations in one of the following quality parameters from the target value are detected:

- Harmonic diameter of sinter
- Sinter basicity
- Sinter $SiO_2$ content
- Sinter MgO content
- Sinter total Fe content

Additionally, fluctuations in raw material analyses are detected and the new optimum raw mix composition is calculated immediately, downloaded to the Level 1 automation system, and executed there. Obviously this proactive compensation of raw material fluctuations is much faster than waiting to see effects in the produced sinter.

## 5. Summary and outlook

The sinter automation and optimization described in this chapter offers an integrated approach for ore preparation and sintering operations in one system, assuring optimal coordination of both plants. The application of the proven closed-loop expert system leads to transparent and reliable process control and shift-independent sinter quality at a high productivity level. The development of this system was an important step in the fulfillment of the vision of "fully automatic sinter plant operation".

Before the described VAiron Sinter automation system has been developed, an analogous automation package for blast furnaces was introduced by Siemens VAI in cooperation with voestalpine Stahl. These systems have in common that they optimize a single aggregate. If an iron making plant contains several blast furnaces and sinter plants, each system would optimize a single aggregate.

Optimal conditions for a group of aggregates differ in general from optimum conditions at each of the single aggregates. In consequence, the next step of development is the VAiron Productivity Control System, which consists of a superordinated expert system considering the whole iron making plant rather then single aggregates. The system considers the

- Coke oven plants
- Sinter plants
- Sinter stock yard
- Blast furnaces

of the iron making plant and coordinates all these aggregates. The system executes its suggestions by sending set-points to the individual Level 2 systems of the single aggregates. Up to now, a prototype of the VAiron Productivity Control System is installed at voestalpine Stahl with promising results.

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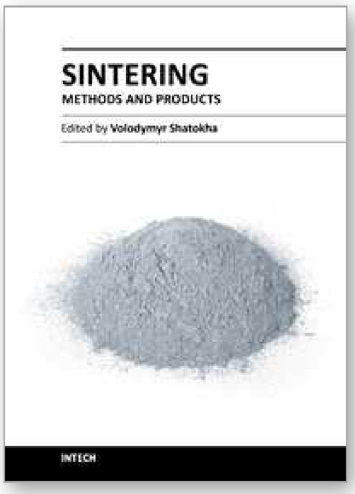


**Sintering - Methods and Products**

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This book is addressed to a large and multidisciplinary audience of researchers and students dealing with or interested in sintering. Though commonly known as a method for production of objects from fines or powders, sintering is a very complex physicochemical phenomenon. It is complex because it involves a number of phenomena exhibiting themselves in various heterogeneous material systems, in a wide temperature range, and in different physical states. It is multidisciplinary research area because understanding of sintering requires a broad knowledge - from solid state physics and fluid dynamics to thermodynamics and kinetics of chemical reactions. Finally, sintering is not only a phenomenon. As a material processing method, sintering embraces the wide group of technologies used to obtain such different products as for example iron ore agglomerate and luminescent powders. As a matter of fact, this publication is a rare opportunity to connect the researchers involved in different domains of sintering in a single book.



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