Model based process control of the Megasteel steel plant

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The steel making plant of the Megasteel Sdn, Bhd., Kuala Lumpur, Malaysia comprises two production lines, each consisting of a shaft furnace with fingers, a ladle furnace and a VDOB facility. As part of the construction of this new minimill, a turn-key Level-2 Process Automation System was supplied and commissioned by the PSI-BT AG, Düsseldorf. The main task of the Level-2 system is to control and monitor all production steps and the material flow from the scrap yard to the take over of the heat at a CSP plant. In order to guarantee the high demands of the CSP facility concerning the liquid steel quality, and to achieve a high level of reproducibility, the system comprises extensive automatic control functions for all facilities which are based on dynamic process models. For support of the quality management and for complete documentation of the production process, all relevant process data are stored in a long term archive and are available either as printed reports or via remote data base access. Therefore, the automation system is integrated into the enterprise wide computer network and communicates with the Basic Automation System, the Production Planning System, the CSP Automation System and the Lab Computer. It has been in successfull operation since mid 1999 and is at present in the final tuning phase of the process models.

Figure 1: Megasteel Minimill, Kuala Lumpur, Malaysia

Minimill with CSP Facility

The Megasteel Sdn. Bhd. has erected a new minimill with CSP facility in Klang, west of Kuala Lumpur, the capital of Malaysia, for a yearly production of over 2 million tons of hot strip. Megasteel belongs to the Lion Group, one of the greatest industrial conglomerations of Malaysia, comprising more than 200 companies. In the middle of 1996 the SMS Demag AG signed the contract to build the steel plant, the CSP facility and a skin pass rolling mill. The minimill consists of two production lines, each consisting of a shaft furnace with fingers and continuous feeding of hot briquetted iron (HBI), as well as a secondary metallurgy treatment unit, consisting of a ladle furnace and a VDOB facility. The CSP facility comprises two casting strands, two pusher type furnaces, and a rolling mill with six rolling stands. Thin slabs of 50 mm thickness and lengths between 900 and 1560 mm are cast, which are rolled as hot strip down to a minimum thickness of 1.2 mm.

Figure 2: Finger Shaft Furnace

The finger shaft furnaces have a capacity of 160 tons each. With a nominal capacity of 90 MW a minimum tap-to-tap time of 44 minutes can be reached. Depending on the qualities produced up to 60 % HBI are fed continuously.

Within the context of this construction project SMS Demag AG, Düsseldorf, and SMS Mevac GmbH, Essen, commissioned PSI-BT AG, Düsseldorf, to deliver a turnkey Level-2 automation system with model-based process control for the entire steel plant, **figure 1**.

General view of the Level-2 System

To meet the high quality demands on temperature and steel analysis with respect to perfect casting characte-ristics and surface conditions in the CSP facility, a model-based process control during steel production is indispensable. PSI-BT AG has substantial know-how in this field. In close cooperation with the BFI Betriebsforschungs-institut models for automated process control of arc furnaces and various secondary metallurgy facilities have been developed, which are tried and tested in practice due to a large number of joint projects. On this basis the MBSP standard (model based steel production) has been created, a modular system that meets the following *requirements*:

- High availability and reliability
- Fully integrated and comprehensive automation of the complete chain of steel making
- Open interfaces for easy integration in plant-wide automation concepts with close connection to production planning (PPS system)
- Open interfaces to basic automation (Level-1) and other computer systems (CSP facility, Laboratory, Level-3)Open, modular and flexible software architecture

The essential tasks of the automation system are: Control and monitoring of production steps, material flow and resources for the complete production chain from scrap yard to handover at the CSP facility.

Model-based automated process observation and control for arc furnace, ladle furnace, and VDOB facility.

The *material and treatment tracking* comprises the following functions:

- Tracking of stock transfer on the scrap yard (bucket charging and material delivery)
- Tracking of all scrap buckets and ladles in the steel plant
- Monitoring of bunker allocation and material availability
- Chronological tracking of all treatment steps and storage of consumption data for energy, material and resources
- Heat and production reports
- Long term archiving of measurement and production data for analysis purposes

The automatic process control of the arc furnaces, **figure 2**, and the ladle furnaces is based on *metallurgical and thermal real-time models* of the BFI Betriebsforschungsinstitut, which are described in more detail below. For process control of the VDOB facilities a model of SMS Mevac could effortlessly be integrated into the automation system thanks to the open interface architecture of the MBSP standard.

The process models observe the actual status of the heat and calculate the necessary setpoints for material and energy input in order to reach the required quality in time. These setpoints are continuously recalculated and downloaded to the basic automation system.

The *model-based process control* comprises the following functions:

- Calculation of the charge materials and generation of bucket loading orders
- Continuous calculation of the actual heat status at all facilities
- Automatic control of electrical energy input with thermal monitoring of the wall elements, as well as HBI and lime feeding at the EAF
- Automatic control of electrical energy input at the LF
- Automatic control of vacuum pumps and oxygen blowing at the VDOB facility
- Alloy calculation for the ladle additions
- Automatic registration of EAF standstills for delay reports

For optimisation of the energy consumption an *intelligent power demand control* with a close link to the EAF and LF process control is another essential part of the automation system. This provides energy saving and a high degree of utilization especially during peak-load periods. As energy is restricted during peak-load periods it is distributed to the controllable consumers EAF and LF, depending on dynamic priorities, which result from the production progress of each facility. Interruption or reduction of electrical energy supply during time-critical production steps are thus avoided as far as possible.

System Configuration

The configuration of the automation system and the network topology are shown in **figure 3**. Two OpenVMS

Alpha systems are used as application and database servers with relational database and PC clients under Windows NT as operator terminals in the pulpits.

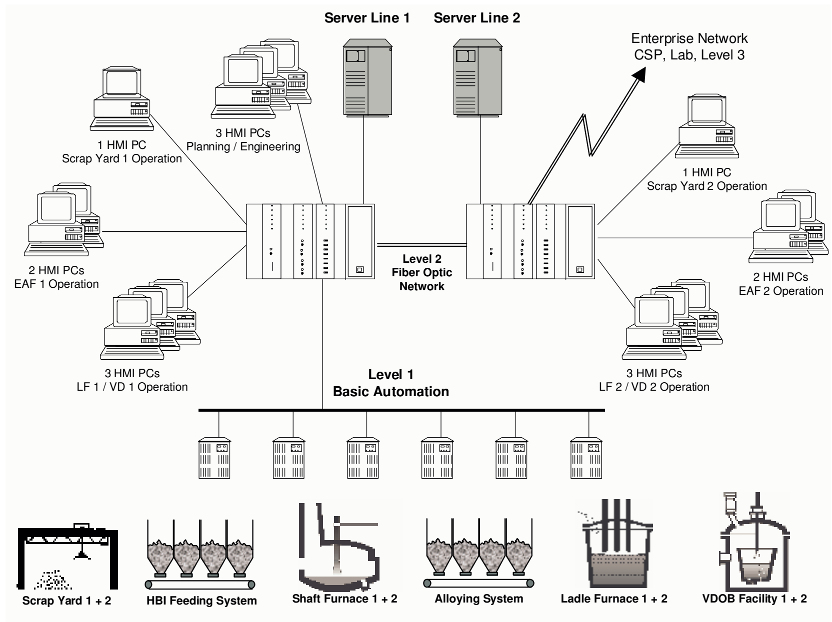

Figure 3: System configuration and network topology

A hub-based fibre optic network of several bridges and repeaters networks the two servers and the entire Level-2 periphery with each other and provides the link to the bus system of the basic automation and the other computer systems within the enterprise network.

Altogether the following hardware is linked:

- 2 AlphaServers with 15 PC clients and network printer
- 10 Siemens S5 PLCs of the basic automation
- 2 AlphaServers of the CSP facility
- 2 AlphaServers at production planning level
- 1 Laboratory
- computer

In addition a network agent with appropriate software for network configuration and monitoring is installed in the hub, as well as a modem for remote diagnosis and system maintenance. Data exchange between the different automation levels is accomplished using the SINEC H1 protocol and TCP/IP based telegram and database interfaces.

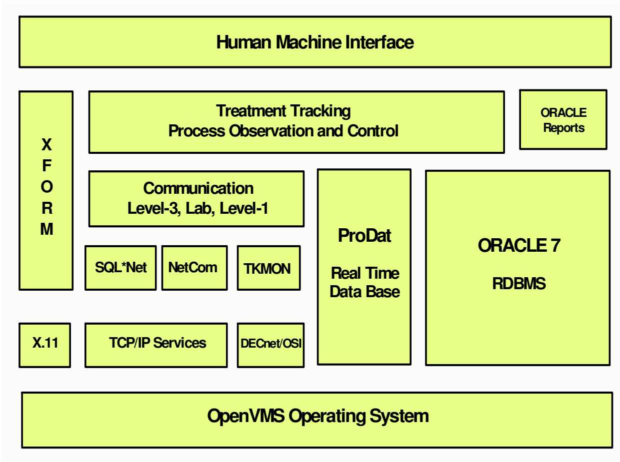

Figure 4: Structure of the level 2 software and functions

The computers form autonomous systems for their respective production lines. Yet, to meet the requirement for data integrity and to support a change of lines of the steel ladles during production, the databases of both systems are automatically balanced using special replication mechanisms.
The **Software Functions** of the Level-2 application have a modular, multi-layer, extensible software architecture, shown in **figure 4**. It consists of *basic software*, which can be configured by parameters, like:

- Real-time and ORACLE® data base
- SINEC H1 communication
- TCP/IP stream socket communication
- Graphical user interface (GUI)

and of *project specific adaptations of standard software modules*:

- Human-machine interface (HMI)
- Material flow and treatment tracking
- Metallurgical and thermal process control
- Communication and
- Reporting.

The **Human-Machine Interface (HMI),** based on a window-oriented graphical user interface is installed on the 15 client PCs in the pulpits for visualization and operator control.

It is based on a PSI-BT standard software package and consists of separate menus for *operator guidance* in the pulpits of EAF, LF, VDOB facility, and also at the scrap yard. Further dialogs are available at engineering workstations for administration, maintenance and update of master and production data, e.g. quality and practice data, operating diagrams, material specifications, and model parameters. The user interface has been developed with respect to the following aims:

- Few, clearly structured forms
- Frequently used functions can easily be executed using function keys or buttons
- Operator input is checked for plausibility
- Critical setpoints must be confirmed before they are passed to the basic automation
- Automatic prompts to the operator during treatment
- Dialogs with critical data are protected by password

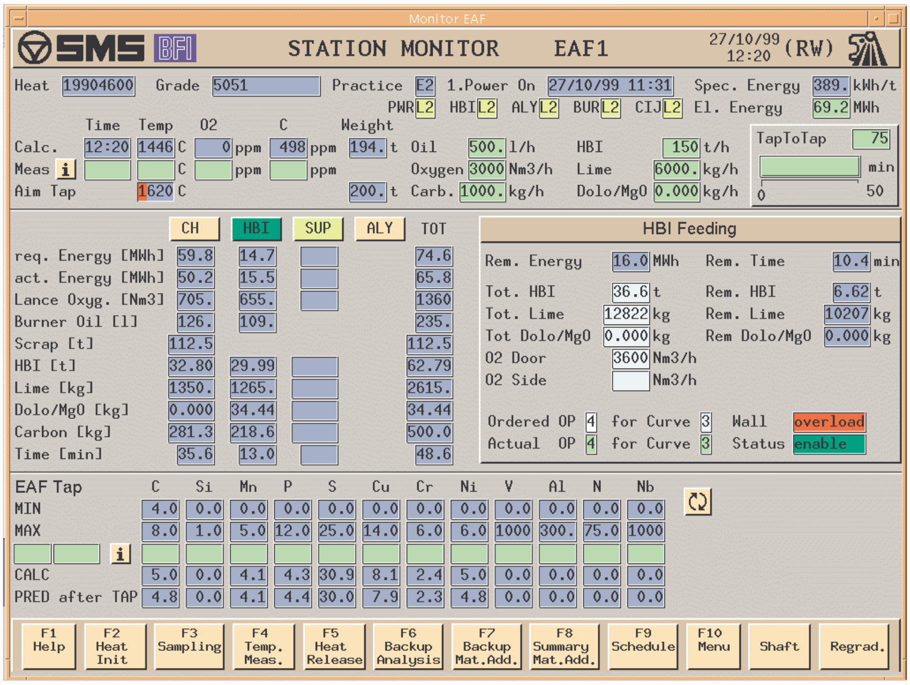

Figure 5: EAF station monitor during HBI feeding

For automatic process control and heat treatment in the so-called Level-2 mode the operator needs *only one dialog*, namely the Station Monitor. Here, all relevant data, like measured values, the results of the real-time process observation, and the calculated setpoints for each process step are displayed. As an example **figure 5** shows the EAF Station Monitor during continuous HBI feeding. Further windows for display or input of detail information and data are displayed either automatically or on demand by pushing function keys or buttons.

Model-based process observation and control for EAF and LF

Process observation and control for the electric arc furnaces and the ladle furnaces is based on metallurgical and thermal process models. Its structure is shown in **Figure 6** together with an overview of the engineering data which are stored on the Level-2 computer, the measured process data which are transferred from the Level-1 PLC control system and the lab computer system, and the control setpoints which are downloaded to Level-1.

Process observation calculates the *current heat status* which includes steel weight, analysis and temperature, and for the LF additionally slag weight and composition. The calculation for the EAF starts with the status of the hot heel, which is estimated after tapping of the previous heat from its final status and the measured tap weight. During treatment, the heat status is updated cyclically and after event inputs like charging of a scrap bucket, material additions or temperature measurements.

The current steel temperature is calculated within an *energy balance*. For the EAF it considers the required melt down energy of all charged and continuously fed materials according to their amounts, and the specific energy requirements which are defined within the Material Specification Data. Furthermore, cyclic energy losses by radiation, waste gas, cooling water as well as electrical losses are considered.

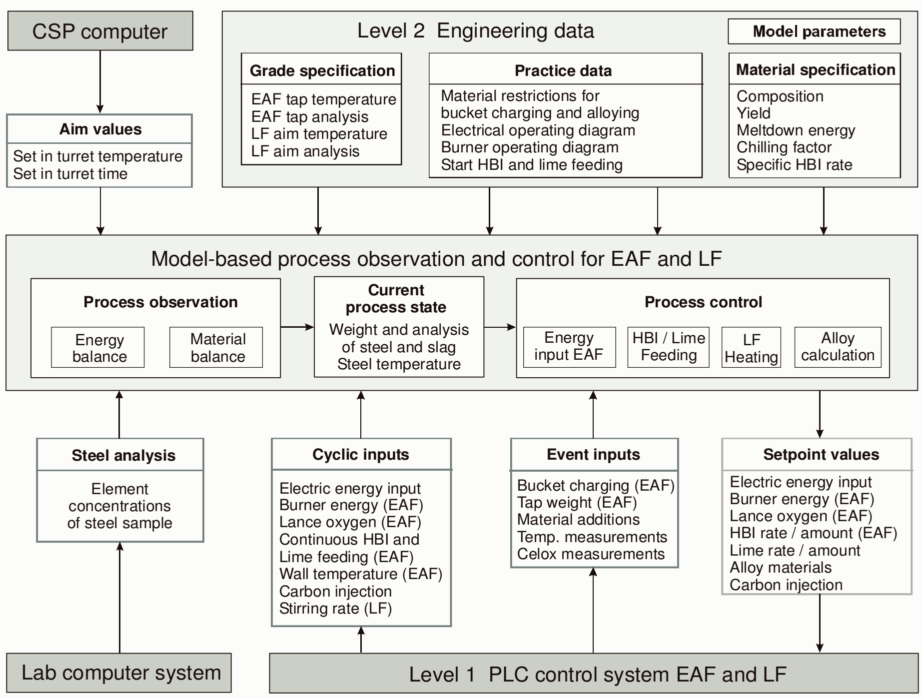

Figure 6: Structure of model based process observation and control

As inputs the electrical energy and the energy from oxyfuel burners and oxygen blowing are taken into account. The energy input by preheating of the scrap is considered according to its residence time in the finger shaft. For the treatment in the ladle the energy losses by radiation, stirring and material additions are compensated by the electrical energy input and the energy input by deoxidation reactions. The difference between the required and the supplied energy defines the current steel temperature. The energy balance is adapted according to each plausible temperature measurement.

Current steel weight and analysis are calculated within a *material balance*. The effect of all added materials is considered according to their yield and composition, taking into account relevant metallurgical reactions like reduction of FeO from the HBI material and deoxidation by Aluminium and Silicon according to the stoichiometric and equilibrium conditions. The currently calculated analysis is adapted to the analyses of steel samples transferred from the lab computer.

Automatic process control calculates the setpoints for control of energy input and material additions according to the aim values of steel analysis and temperature defined in the grade specification. The calculation is based on the current process state, taking into account restrictions and rules coming from the Practice Data.

Process control at the EAF. The normal operation at Megasteel is that about 30 t of HBI, 70 t of scrap and 35 t of pig iron are charged with two buckets. The contents of the first bucket are charged onto the closed fingers of the shaft for preheating during the previous heat. After tapping of this heat the fingers are opened and the preheated materials are charged into the furnace. The second bucket is charged into the open shaft before first power on. The aim tap weight of 160 t is achieved by continuous feeding of about 40 t of HBI. **Figure 7** shows the corresponding pattern of electric energy input and HBI feeding.

The *electric energy input* is controlled automatically via an operating diagram, where the power setpoints for several meltdown steps are defined. After start of meltdown, these setpoints are selected according to the achieved specific electric energy input to increase the active power to its maximum value in three steps. In case of a thermal overload of the wall panels the power is automatically decreased by setpoint modification.

When the specific energy input has reached a value predefined in the practice data, the start of *continuous HBI feeding* is recommended and started after operator confirmation. The total amount of HBI to be fed is calculated depending on the already charged materials, in order to achieve the scheduled aim tap weight. Parallel to HBI, lime is continuously charged to maintain a given slag basicity for slag foaming and dephosphorisation. The total lime amount to be fed is calculated according to the aim slag basicity and the gangue of the HBI material.

The *HBI feed rate* is determined from minimum and maximum values of a specific feed rate given in kg / MW min, which are defined in the Material Specification Data for each different type of HBI material. At HBI feeding start this specific HBI feed rate is increased continuously, beginning with its minimum value and reaching the maximum value when the energy input for complete meltdown of the bucket materials is achieved.

The actual HBI feed rate is cyclically calculated from the specific feed rate and the current power input, given by the electric active power and the power input by oxygen blowing. Therefore the feed rate reflects the scatter in the power input, which is amongst others Things strongly influenced by the power requirement of the other furnaces in the steel making plant. By this the generation of icebergs is avoided, which occurs more likely when operating with a fixed feed rate.

temperature measurement tapping into the ladle is started.

During tapping a part of the alloy

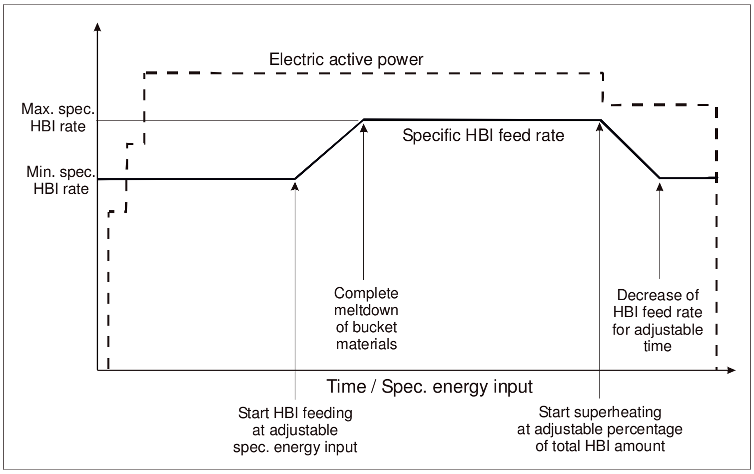

Figure 7: Control pattern of electric energy input and specific HBI feed rate

During HBI feeding closing of the shaft fingers and charging of the first bucket of the following heat for preheating is recommended after reaching a predefined specific energy input.

HBI feeding is continued with the maximum specific feed rate until the charged amount of HBI has reached a predefined percentage of the total amount. At this point the start of the socalled Superheating step is recommended and started after operator confirmation. During superheating the specific HBI feed rate is decreased again and reaches its minimum value after a predefined time. By this the melting conditions are improved and the steel bath is homogenised with respect to its temperature. For the Superheating step the electric active power can be decreased according to a new power setpoint defined in the electrical operating diagram, in order to reduce the thermal wall-load.

HBI feeding is stopped on Level-1 automatically when the complete HBI amount has been charged. The steel bath is superheated to the aim tap temperature, and after a final material amounts which are necessary to achieve the aim analysis, as well as aluminium for deoxidation and lime are charged into the ladle. For time saving the materials have to be preweighed during HBI feeding, so that they are already prepared at start of tapping. Therefore the amounts to be charged are defined in the practice data depending on the steel grade. The remaining alloys for achievement of the final aim analysis are added during the following secondary metallurgy treatment.

After tapping, the heat status in the ladle is calculated from the final status at the EAF, considering the effect of ladle additions. Thus the start condition for the following treatment station is defined.

Process control at the LF. The ladle furnace treatment starts with a short heating period for melting of the slag and thermal homogenisation of the heat. This heating period is controlled via setpoints for heating rate and energy input which are defined in the practice data. The corresponding setpoints for voltage tap and arc length are downloaded to Level 1 automatically. After a first plausible temperature measurement the heating rate is calculated which is required to finish the heat with the aim temperature at a given time. The alloy materials which are necessary to achieve the aim analysis are calculated under minimum costs based on the currently calculated analysis, considering restrictions from the practice data concerning the allowed materials and the current material stock in the bin system.

Synchronisation with the CSP facility. To synchronise production, aim values for *handover time and temperature* are cyclically received from the CSP computer. The heating process in the ladle furnace is controlled according to these aim values by continuously updating the calculation of the required heating rate. If necessary, new setpoints for voltage tap and arc length are automatically sent to the basic automation. Temperature losses by future treatment steps during heating, e.g. alloying, are already taken into account. In addition temperature surplus and time reserves are held for cleanliness stirring and wire addition after heating and a possibly scheduled treatment at the VDOB facility. In response to the aim values the expected handover time and temperature are calculated and passed to the CSP computer, which may in turn adapt the casting speed as necessary.

Adaptation of model calculations:

- The model calculations for process observation and control were tuned by adjustment of the Level-2 practice data and the model parameters. The main aims were to optimise the accuracy of the process observation, to minimise the on-to-tap-time of EAF treatment, and to improve the performance of HBI feeding as well as the accuracy in meeting the CSP aim values. In the following the most important actions are described:
- The model parameters and material specification data which are relevant for observation of the steel temperature are adapted by evaluation of heat data, in order to minimise the difference between calculated and measured temperature. When the accuracy of the cyclically calculated steel temperature is sufficient, the number of required temperature measurements can be reduced.
- The setpoints of the electrical operating diagram are optimised to increase the active power during scrap meltdown in the EAF as fast as possible, but ensuring a sufficient protection of the furnace roof and side walls from arc radiation.
- To avoid HBI accumulations in the furnace, the start time of HBI feeding is optimised to ensure feeding into a hot molten steel bath.
- The maximum specific HBI feed rate is adjusted to avoid the generation of icebergs during the main feeding phase.

These adjustments can be realised very fast due to the flexibility of the application software, which provides easy, efficient and reliable means for operation and maintenance of the Level-2 system.

With a similar system for model-based process observation and control, at the steel plant of the Alexandria National Iron and Steel Company, the productivity was increased remarkably [1].

References

[1] Beltagi, I.; El-Dakhakhny, W.; Kleimt, B.; Ponten, H.-J.; Matissik, W.: MPT 22 (1999) Nr. 4, S. 66/72

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