CAST IN TIME AND QUALITY: ENERGY SAVINGS THROUGH INTEGRATED HEAT TEMPERATURE FORECAST AND SCHEDULING MODEL[1]

Energy Savings Through Integrated Heat Temperature Forecast and Scheduling Model

Heinz-Josef Ponten[2]
Bernd Kleimt[3]

Abstract

An integrated IT system of heat schedule prediction and temperature development was designed to control the energy consumption from BOF converter or EAF tapping through ladle treatment in secondary metallurgy to the delivery of the heat to the caster in time. The system ensures that the heat is handed over for continuous casting on time and with the right temperature, depending on the aim of optimization (maximum throughput or minimum energy costs). A dynamic model calculates the thermal development throughout the process steps considering the actual real-time heat scheduling results. Based on these results, the adjustment of the BOF tapping temperature or the energy input in the ladle furnace is optimized according to current workload situation of the resource. Temperature changes are taken into consideration during planning to optimize the entire time to produce a heat. Optimization of ladle circulation keeps every ladle in the cycle to reduce average ladle reheating and circulation times. The system brings about significant energy savings for oxygen and electric steelmaking plants.

Key words: Steel making scheduling; Energy savings; Temperature model.

Resumo

Um sistema integrado de previsão do sequenciamento e evolução da temperatura das corridas foi projetado para controlar o consumo de energia a partir do convertedor BOF ou forno elétrico EAF, metalurgia secundária, até as máquinas de lingotamento. O sistema assegura que a corrida é entregue a tempo, e com a temperatura apropriada, para as máquinas de lingotamento contínuo, em função do objetivo de otimização (maximizar o 'throughput' ou minimizar custos energéticos). Um modelo dinâmico calcula a evolução térmica através das diferentes etapas do processo, considerando informação de sequência de panela em tempo real. Em base a esses resultados, o ajuste da temperatura no forno, ou a energia injetada no forno panela são otimizados, dependo da carga real do recurso. Mudanças de temperatura são consideradas durante a programação para otimizar o tempo completo de produção de uma corrida. A otimização da circulação das panelas mantém cada panela em ciclo com a finalidade de reduzir o tempo promédio de reaquecimento e o tempo promédio de trânsito. O sistema aporta ganhos significativos para aciarias.

Palavras-chave: Aciaria; Economia de energia; Modelo de temperatura.

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[2] *Dipl.-Ingenieur, Manager Business Unit Steelmaking PSI BT GmbH, Germany*
[3] *Head of Department Process Automation Steelmaking , VDEh-Betriebsforschungsinstitut GmbH (BFI), Germany*

INTRODUCTION

Within steel making an important control parameter with relevance for energy consumption is the adjustment of the target casting temperature of liquid steel. An optimized temperature control is particularly important for steelmaking plants in which the entire energy buffer to compensate losses during secondary metallurgy ladle treatment has to be adjusted before tapping of the primary steelmaking plant or during a consecutive ladle furnace treatment.
To avoid an unnecessarily high energy input in the BOF or the LF, which has to be lowered during ladle treatment e.g. by cooling scrap addition or stirring, a system for through-process prediction of temperature evolution within the complete steelmaking route has been developed. It covers the primary steelmaking process from BOF converter resp. EAF tapping via the ladle treatment in different secondary metallurgy facilities up to the delivery of the heat to the caster. The effect of the thermal status of the tapping ladle on the evolution of the steel temperature loss rate is considered within the dynamic model calculations.
On the basis of the dynamic through-process temperature prediction, which is performed for the entire treatment already before BOF or EAF tapping, the adjustment of the BOF tapping temperature resp. the electrical energy input in the Ladle Furnace is optimised, so that further temperature control actions during ladle treatment like cooling scrap additions, stirring or chemical heating steps are minimised.
The system for through-process temperature control is applied an oxygen and an electric steelmaking plant, leading to significant energy savings.

MATERIAL AND METHODS

Model based through-process temperature control

The process of steel making is connected with a high energy consumption. Normally at the primary facility or at a ladle furnace an energy buffer is built up to compensate the losses during the following ladle treatment. The aim is to deliver the liquid steel with a predefined temperature to the continuous caster. To be on the safe side, the energy buffer is often over-dimensioned, so that afterwards a cooling scrap addition is required to lower the melt temperature. In contrast, a melt becoming too cold for the casting process has to be recharged at the primary steel making facility or reheated at the ladle furnace, which is connected with a high effort of additional energy input and time.
The aim of the project was the development of a system for through-process dynamic on-line prediction of the temperature evolution during steelmaking, and based on this an optimisation of the energy input in the oxygen steelmaking converter resp. in the ladle furnace for adjustment of the aim casting temperature.
In the frame of the project, a model-based online-observation of the melt temperature for treatment in the different plants of the steelmaking route was developed. It was combined with models for determination of the thermal ladle status to a through-process prediction of the temperature evolution. Figure 1 shows as example for the process route in an electric steelmaking plant the predicted evolution of the melt temperature together with the temperature measurements of an example heat.

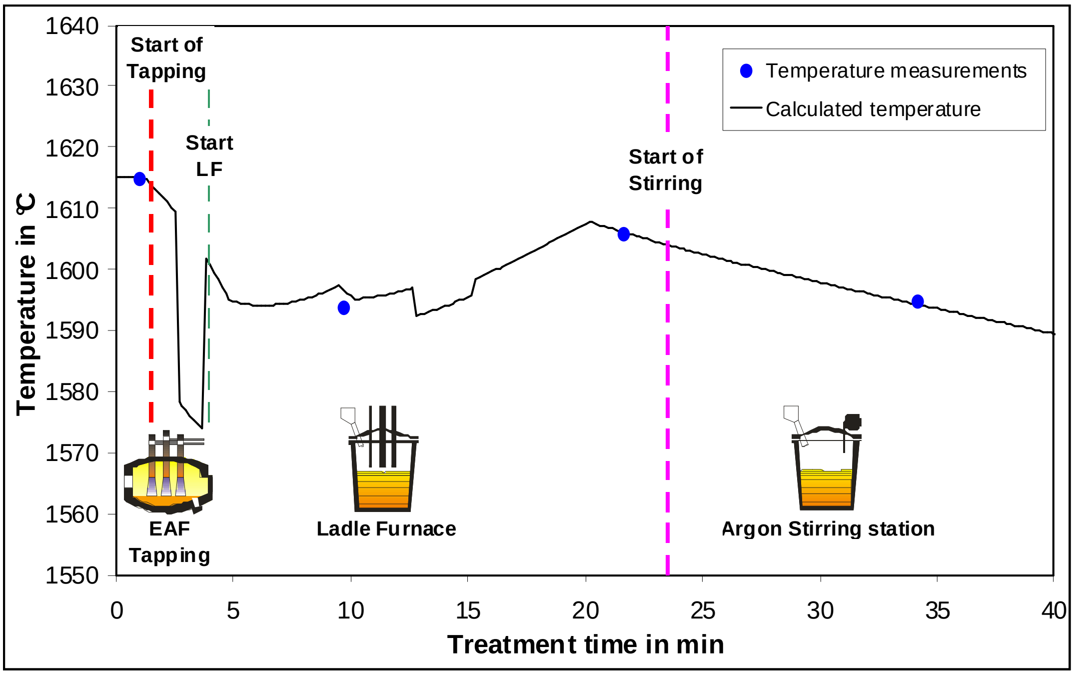

Figure 1: Through-process monitoring of the melt temperature in an electric steelmaking plant.

The prediction of the temperature evolution was used for calculation of set-point values for the tapping temperature at the converter resp. for the electrical energy input at the ladle furnace, for an energy-optimal adjustment of the delivery temperature at the continuous casting plant. In Figure 2 the complete concept of energy optimisation is shown for the oxygen steelmaking route, where often the complete energy buffer for the secondary metallurgy ladle treatment has to be adjusted already at tapping of the converter.

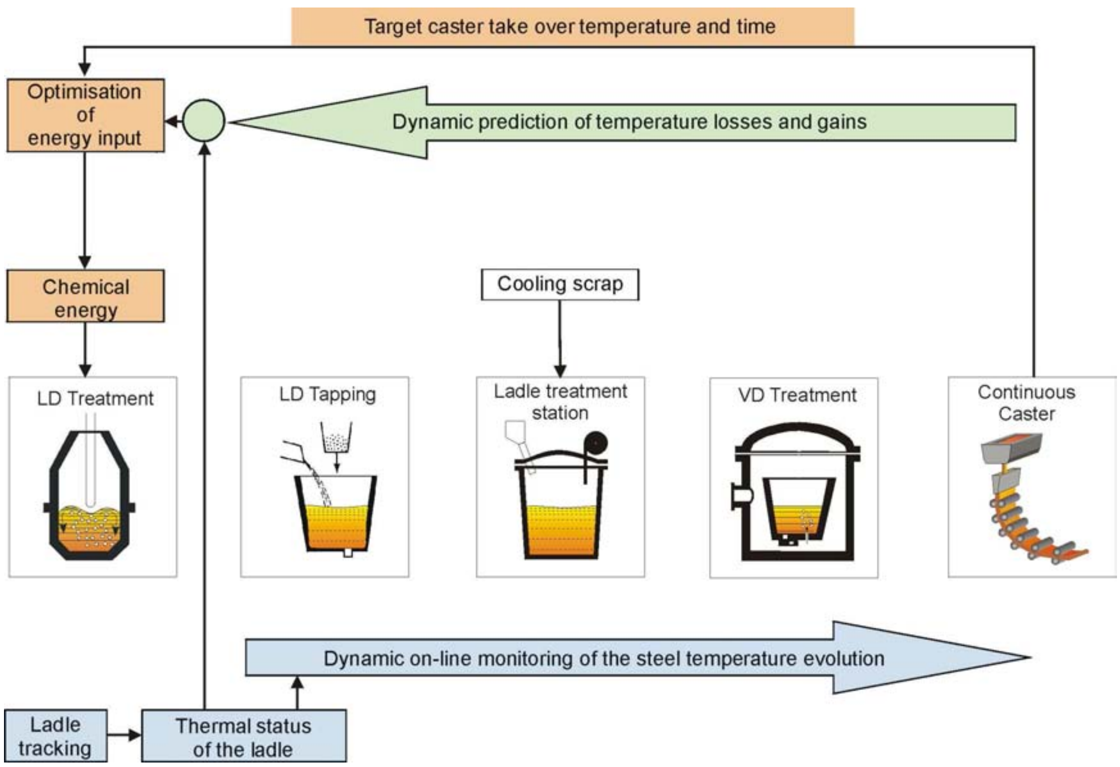

Figure 2: Concept of through-process temperature control in an oxygen steelmaking plant.

Integration of the Temperature Model with Production Scheduling System

German based software solution provider PSI cooperates with the applied research institute VDEh-Betriebsforschungsinstitut (BFI) in Dusseldorf to integrate the analytical-mathematical online process models in its production management software system. The main focus on integrating the BFI temperature model described above into software systems for production planning and control is to enable temperature-controlled scheduling for steel plants. The system controls that the heat is handed over for continuous casting on time and with the right temperature, depending on the aim of optimisation (maximum throughput or minimum energy costs).

The BFI temperature model has been integrated into PSI's production management software, to be able to take the temperature into account as a significant basic restriction for scheduling heats in steel making plants. All temperature-relevant variables are stored in the system's process instructions, which describe all production routes, rules and information to be considered when producing a particular heat. Other factors influencing the temperature in addition to the temperature losses occurring during production flow, such as alloying and other material additions, are also calculated and taken into consideration. The logistic tracking of every single ladle in the steel plant by the production planning and control software enables the BFI model also to exactly consider its thermal condition and its impact on the temperature development.

The model's input variables are, on the one hand, specifications provided by the production management system for treatment and transportation times as well as calculated target values for material additions, electrical energy input, etc., and on the other hand, the ladle temperature loss rate and losses through heat treatment and material additions. To achieve the target temperature, the BFI model predicts the heat temperature for the remaining treatment steps on the basis of the current process condition determined via online monitoring. The prediction is updated cyclically and event-driven whenever a relevant treatment step occurs, e. g. when laboratory analyses and new temperature measurements become available and when materials are added and treatment steps are started or finished.

The planning process for the steel plants defines a sequential schedule for treating the heats with optimised temperature buffers for all facilities upstream from continuous casting on the basis of target treatment times and target temperatures. Changes in production flow as well as unplanned interruptions and delays lead to new predictions which are visualised in the production management software due to the integration of the model. This is important to the extent that every chronological change in production flow has a direct impact on temperature. Temperature-guided planning allows temperature changes to be taken into consideration during planning to optimise the entire time schedule of a heat production order. Planning the ladle circulation also plays an important role as ladles that are empty for any significant amount of time not only cool down but also cause a higher temperature loss rate. The scheduling software optimises ladle circulation with the aim of keeping every ladle in the cycle (taking ladle history into consideration) to reduce the average ladle re-heating and circulation times.

Depending on the processing route (converter steel plants, electric steel plants, ladle furnace yes/no) the software enables the scheduler to optimise various targets with regard to quality, cost, time and productivity. For instance, throughput optimisation usually requires greater energy expenditure to treat as many heats as possible when the facilities are working to capacity. This can be expedient when the order books are full and profits are sufficient to cover the higher cost of energy. The response to a drop in demand is a continuous reduced facility output whilst maintaining throughput with a focus on energy cost minimisation. The system will make recommendations on what can be influenced by the dispatcher depending on the optimisation target. Can existing buffers be used up? Should the tapping temperature be reduced? Should casting speed be increased? It calculates the effects of changes to the speed of casting and how and when buffer times and temperatures can be utilised.

RESULTS

The scheduling model for capacity optimization and electrical energy consumption forecast was installed and tested at steelmaking plant of Swiss Steel AG in Switzerland. The model for optimised temperature control was installed and tested at the oxygen steelmaking plant of Hüttenwerke Krupp Mannesmann GmbH (HKM). With the help of the system for optimised temperature control, at HKM the converter tapping temperature was lowered on the average by 10 K. This corresponds to energy savings of about 5 kWh/t.
A further installation of the model for optimised temperature control together with the integrated software solution for production planning and control was installed at the electric steelmaking plant of Peiner Träger GmbH (PTG). In the electric steelmaking plant of PTG the decrease of electrical energy input at the ladle furnace was estimated to 2.4 kWh/t.

DISCUSSION

The planning solutions for steel plants available on the market mainly focus on time schedules, capacity and sequence as restrictions for planning. The temperature as a major process variable and how it changes during production process in comparison to the required target temperature is often left unconsidered. When steel is produced without a ladle furnace the assessment as to whether the casting temperature will be attained at the end of the process or if there is a danger of having to stop casting depends on the experience and competence of the operators and dispatchers; it also requires internal coordination to correctly evaluate the impact on follow up production orders and facilities. This gap has been closed by the integration of the BFI temperature model into PSI's production management software which takes the temperature into account as a significant basic restriction for scheduling heats in steel making plants.

CONCLUSION

The direct integration of the BFI temperature model into software for production planning and control enables the temperature development in any production stage to be taken into consideration during scheduling. Energy buffers that "feel right" but are in fact too high can be reduced, treatment times cut and the overall energy costs of the treatment process lowered without increasing the risk of production downtimes.

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Heesen, Markus, Faculty of Mathematics University Duisburg-Essen

BIBLIOGRAPHY

Grob, Sebastian: Mathematical Scheduling Model, Technical Bulletin, PSI BT GmbH, Dusseldorf, 2008.
Kleimt, Bernd, M. Weinberg, J. Bongers und M. Schöring: Dynamic through-process prognosis of steel-temperature to optimize energy input and temperatur control during steelmaking, Technical Bulletin, VDEh - Betriebsforschungsinstitut, Dusseldorf, 2009.
Heesen, Markus: Online heat scheduling under consideration of capacity and temperature, Diploma Thesis, University Duisburg-Essen, 2010.