Results of Implementation of ZapTech Proprietary Technologies in BOF Shop of Třinecké železárny

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The presentation discusses the result of the implementation of flexible technologies of ZapTech (USA) at Trinecke Zelezarny. It describes the results from the use of carbon fuel which allowed to increase the share of scrap up to 36%, and also the uses of preheating of scrap by gas coals which provide secure operations in winter and an increase in yield of liquid steel. The presentation demonstrates results of many years of use high-magnesia content, non-hydroscopic sinter, which allowed to work without burnt dolomite, reduce cost of fluxes and improved the lining life of the converters. Also provided are the results of use of complex of ZapTech mathematical models that provide:

- *based on the predictions of the slag condition - the prevention of splashing during heat;*
- *based on the dynamics of changes in the composition of the gases - high-precision targeting of the specific aim parameter at the taping;*
- *based on two level correction of the technological parameters of the process of steel production – optimization of the results of the main parameters of the heat at the taping*

Introduction

TRINECKE ZELEZARNY (TZ) is a traditional integrated mill. It has four strands at the sinter plant, two blast furnaces, and BOF shop with two 185-ton vessels and rolling mills. The rolling mills produce a wide variety of long products including rails, wire, steel bars, semis, seamless tubes, drawn steel, etc. The plant's goals are to increase profitability through the production of higher quality steel grades.

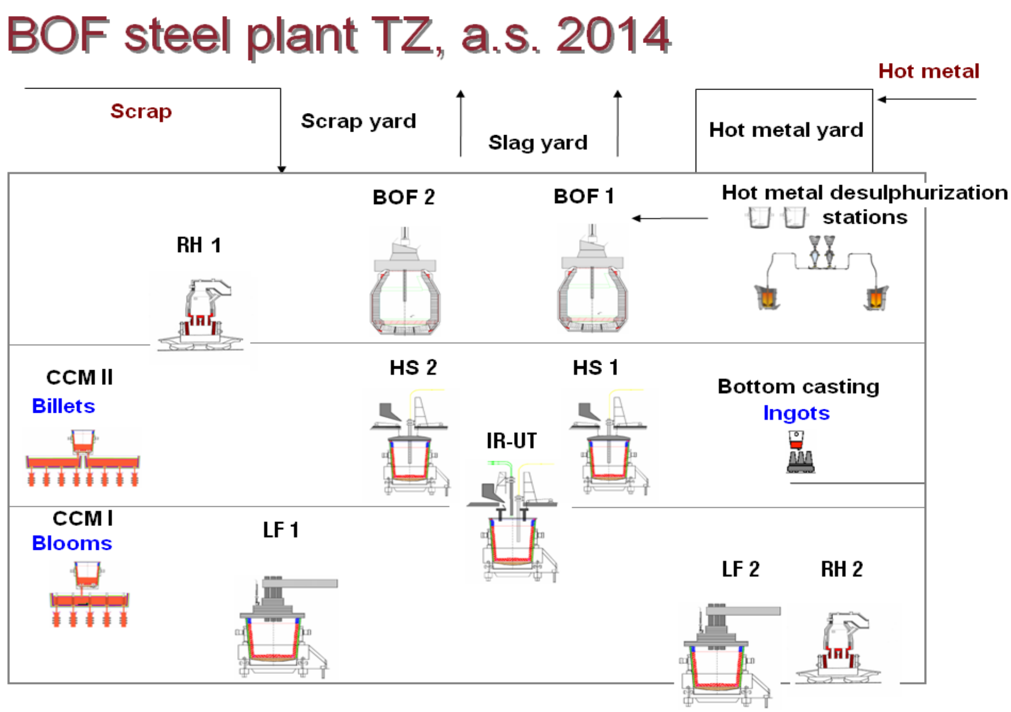


Fig. 1 Layout of TZ BOF shop - 2014

Please allow to briefly describe the technological equipment used in the BOF shop (Figure 1): The converter shop TZ is equipped two hot metal desulphurization stations, operated by two 185 ton LD-converters with bottom inert gas blowing by (argon or nitrogen). At the department of secondary treatment ladle of steel in the BOF shop operate two stations of homogenization, two unit ladle-furnace, and chemical heating station. Steel vacuum degassing is available in a two-station RH-type. There are two continuous caster the bloom caster (5 streams) for range 300 x 350 mm, 320 mm diameter circle, 410 mm, 470 mm or 525 mm, and billet caster (8 streams) to 150 x 150 mm range. Part of the production is poured into ingots using the bottom casting.

The cooperation between TRINECKE ZELEZARNY and ZapTech started in 1998. At that time, TZ BOF shop was experiencing several serious limitations and problems, including:

- productivity which strongly depended on hot metal supply - this was especially problematic since the plant planned overhaul of one of the two blast furnaces;
- high content of phosphorus and sulfur;
- large ranges of physical and chemical heat of hot metal which made difficult the production of high quality steel and required two-stage technology of steel production, etc.

All attempts to substantially change the results of the BOF shop operations through the use of the fuel were unsuccessful. Developed by ZapTech proprietary technologies, so-called “Z-BOP Technologies” were designed to solve similar problems. Therefore, in 1998, Z-BOP Technologies was licensed from ZapTech, which started long-term TRINECKE ZELEZARNY and ZapTech cooperation.

Phase 1

During the Phase 1, the first technology implemented was "basic Z-BOP model for calculation of charge, fluxes, and oxygen for heat and steel making technology using the optimum quantity of solid carbon-containing fuel (coke).

Z-BOP Technologies opened possibility of highly effective use of large quantity of carbon-contained fuel. At the same time, ZapTech’s proprietary methods for slag forming allowed to produce high quality steel (low content of sulfur and phosphorus) and to increase yield, as a result, significantly increased share of scrap in metallic charge, to increase flexibility of the operations of the BOF shop, increase yield and improve the quality of steel. All of these processes were part of Phase 1 of the cooperation. (Figure 2)

The introduction of this technology has enabled the BOF shop to work with higher consumption of scrap metal even at lower physical and chemical heat of hot metal, respectively maintaining the required level of production. Economic effect in this period was 1.5 -2.0 USD/ t.

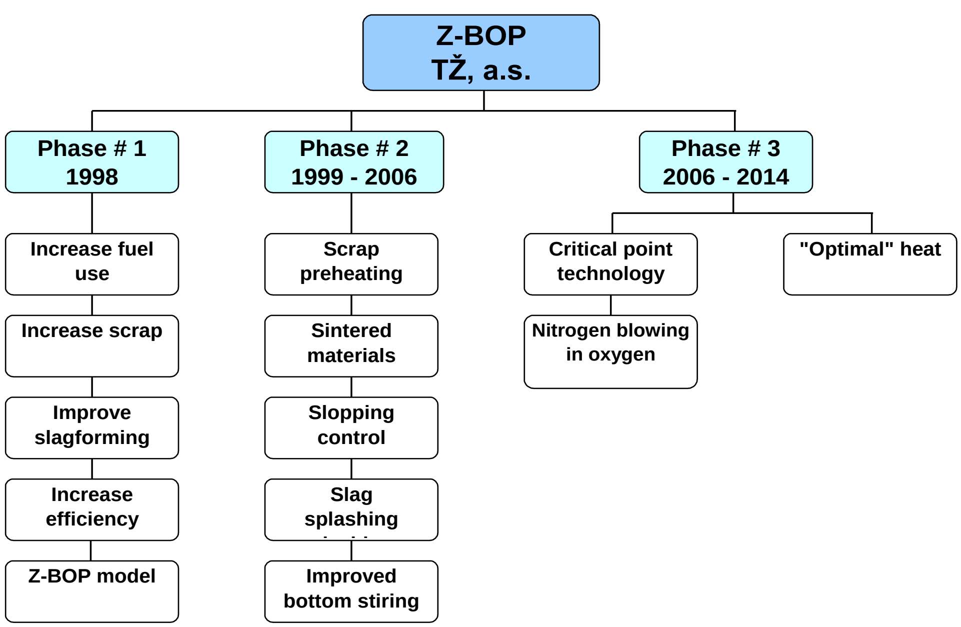


Fig. 2 Phases of implementations

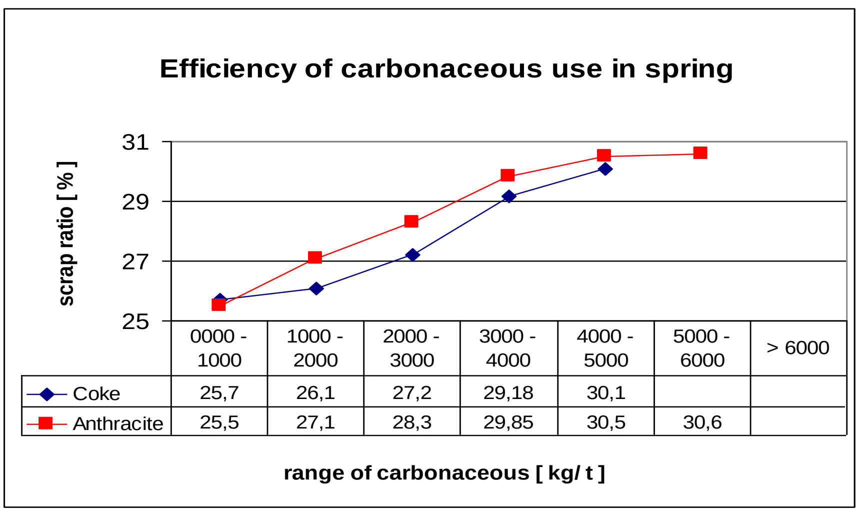
Phase 2

After the initial implementation of Z-BOP technologies, ZapTech's additional proprietary technologies were implemented: the proprietary preheating technology, technology for slopping prediction and control, slag-splashing technology for vessel maintenance and sintered flux material production and use. It should be noted that prior to that phase, all heats were conducted in two-stages because hot metal contained P (0,070 – 0,140%), Si (0,40 – 1,45%) and S (0,010 – 0,050%). At a result, at that time, the steel production was characterized by:

- unstable process pace;
- low yield;
- low scrap portion in metallic charge;
- high consumption of slag forming materials and alloys;
- low lining life;
- low lining life of the bottom plugs;
- high tap to tap time.

Despite the significant increase in share of scrap in metallic charge and use of larger volume of fuel, the implementation of Zaptech's proprietary Z-BOP technologies allowed TZ BOF shop to stabilize the process of steel production, to increase flexibility in consumption of hot metal, and to increase yield and lining life.

In 1999, the optimization of the types of fuels used in the production was completed and new type of the fuel was introduced as well as the technology of scrap preheating with gaseous coals was implemented. Coke was replaced by anthracite to reduce sulfur content and to increase quantity of carbon-containing fuel the allowed in the heat. The use of anthracite permitted to reduce the impact of the humidity, to increase the speed of fuel charging (Figure 3), to increase the effectiveness of use of heat during the process, to reduce the content of sulfur and nitrogen in the steel before taping.



	0000 - 1000	1000 - 2000	2000 - 3000	3000 - 4000	4000 - 5000	5000 - 6000	> 6000
Coke	25,7	26,1	27,2	29,18	30,1		
Anthracite	25,5	27,1	28,3	29,85	30,5	30,6	

Fig. 3 Efficiency of carbonaceous use in spring time

Scrap Preheating

ZapTech's proprietary Scrap preheating technology was implemented in TZ in 1999. One of the construction conditions of TZ BOF shop is the ability to conduct blow on only one of the two BOFs. This ability presented a potential for use of ZapTech's proprietary technology for preheating scrap with bituminous coal in BOF shop.

Z-BOP preheating technology has two modules: short preheating (3-4 min) and regular scrap preheating (depending on the required share of scrap - 6 minutes or more). For an ongoing use at TZ, taking into account specifics of TZ BOF shop, the short preheating module was implemented. Use of this module provided safety of loading of hot metal in the winter conditions, as well as additional increase (~ 2-3%) of share of scrap without any changes in the content of sulphur and nitrogen in the steel.

Figure 4 shows the changes to the content of scrap as a result of use of the preheating stage. It should be noted that the effectiveness of the use of bituminous coal at that stage significantly exceeds the average level of effectiveness of the use of anthracite in the BOF heat. Because of the high effectiveness of this operation, almost 70-80% of the heats in subsequent years are done using this technology (Figure 5).

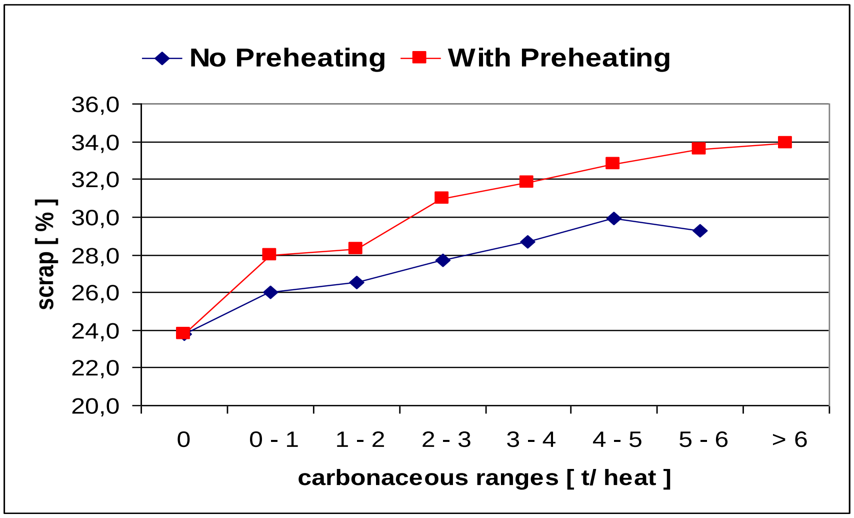


Fig. 4 Efficiency of carbonaceous use at scrap preheating

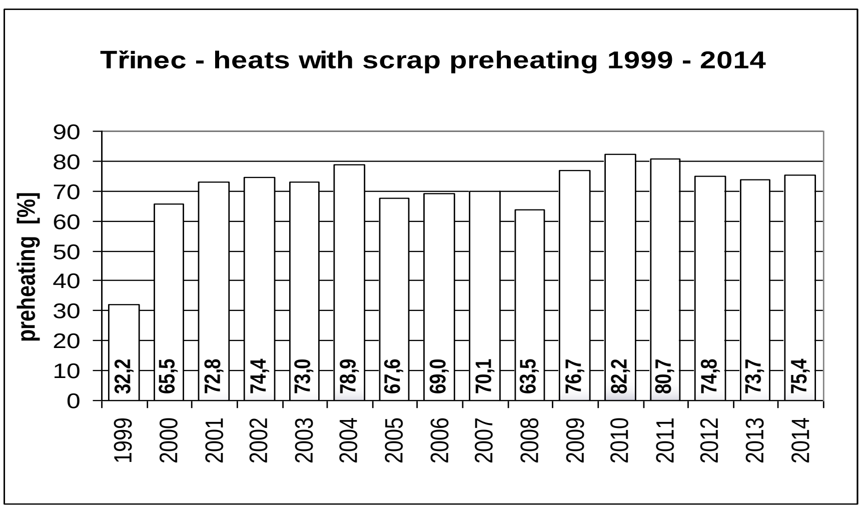


Fig. 5 Scrap preheating evolution

Average scrap ratio at TZ BOF shop prior to the implementation of ZapTech's technologies was approximately 23-25%. After the implementation of ZapTech's flexible technologies, the share of the scrap used in the BOF heat at the shop for many years was averaged at 28%, with some grades of steel using 34%. Changes in the assortment of the produced steel (more complicated grades of steel) and higher cost of scrap, fuel and oxygen forced TZ to change its strategy toward optimization of the share of scrap.

Sintered materials

One of the specifics of TZ was absence of equipment to produce its own dolomite. To remedy this situation, in 1999 ZapTech introduced technology for production of sintered fluxes at Trinecke sinter plant to replace traditional fluxes at the BOF shop. It was determined that three components of sintered flux are required. The design envisaged using sinters for the slag as the source of magnesia, iron oxides and calcium oxides. Despite the positive results from the use of several modifications of the sinter flux, because of the shortage of bin above BOF, at this time only MgO sinter is used. Transition to use of sinter fluxes not only improved slag formation, reduced the use of charging metal, but also reduced the cost of lime and stopped the use of burned dolomite (Figure 6)

MgO sinter material has the following properties:

- non-hydroscopic, strong, thus no problems with reloading;
- may be stored for several months;
- when handled, they are not subject to material degradation;
- use of it for oxygen converters provided better process stability, improved refining and increased steel yield.

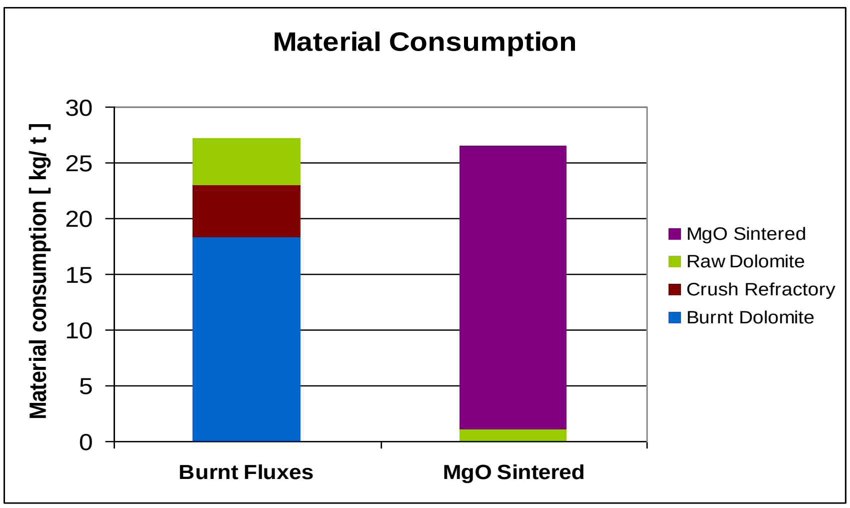


Fig. 6 Material consumption

The MgO sinter has fully replaced previously used dolomite. Use of MgO sinter flux allowed to reduce the use of slag forming materials, to reduce their cost and reduce the amount of oxygen used in the heat. Replacement of dolomite lime with MgO sinter required optimization of technology of input of slag-forming materials, and changing modes blow oxygen. Since MgO sinter is not hydroscopic, it allowed to produce it in large batches on monthly base in TZ sinter plant to be stored and used in TZ BOF shop as needed. In the past years, there were many improvements introduced to the technology to improve properties and characteristics of the sinter material.

Slopping control

Together with the new MgO sinter in BOF process was implemented the technology of Slopping control, which is now in the operation at TZ BOF shop as an everyday tool, and ZapTech keeps refining the technology. Based on the data about the composition of the loaded material, its weight and time of the loading as well as parameters for blow, this technology calculates the sloping potential. All actions were directed to calculate and control the Slag Height. The BOF heat must be conducted in such way that during the blow, the Slag Height should not exceed Critical Slag Height. The maximum slag height is controlled by optimizing the quantity of fluxes, fuels while considering the aim parameters for sulfur, phosphorous, nitrogen. Blow profile, flux profiles, and height of lance (Gap) were also optimized. It is well known that an opportunity to prevent slopping is reduced after each of the corresponding operations during the heat (loading of fluxes, changes in the position of lance, changes in intensity and quantity of blows, etc.). For example if fluxes are prepared in the bin, the only action to prevent the sloping is changes in the blow profile and the chance in the intensity of blow. Possibility of calculation of the potential for sloping allows to significantly expand the chances to avoid it. In our case, as a result of additional changes in the quantity and sequence of batches of flux.

Slag Splashing

TZ began using Slag splashing technology in April 2004. Combining the improvements in process control provided through ZapTech with refractory maintenance improvements provides with slag splashing allows significantly increased lining life, yield of steel and reduce use of gunning mixes.

Optimization of Bottom Stirring

One of the limitations to the lining life of the BOF lining is relatively low lining life of bottom plug. As a result, one of the two BOFs operates without bottom stirring almost 60-70% of the campaign. ZapTech and TZ conducted extensive work toward improvement of the lining life and improvement of the effectiveness of bottom stirring. The work included use of joint blow with nitrogen and argon, treatment of slag build-up on the bottom, optimization of the configuration of the BOF lining and optimization of the taping, etc. The result of these efforts was more than doubling lining life of bottom plugs and provision of practically equivalent lining life of BOF and duration of work vessel with bottom stirring.

As a whole, the use this technologies in the Phase 2 allowed to increase yield, increase production of steel, reduce cost of steel and stabilize production in TZ BOF shop. The economic effect in this period was 1.0 - 7.0 USD/ t.

Phase 3

One of the strength of Z-BOP technologies is the use of proprietary mathematical model~~,~~ which provide its optimal use. Therefore, as part of the use of the technologies during Phases 1 and 2, the parties implemented first level of mathematical models which provide their realization. Starting 2006, with goal to further: improve the effectiveness of the BOF shop's production; improve quality of the steel and to reduce the costs of production, ZapTech together with TZ started systematic implementation of the elements of dynamic control for the use in their modes. As of today, the results of these actions are the use of the complex, 2-level model where second level is based on the correction of the loading parameters of the heat based on the elements of dynamic control technology based on the concept of "optimal heat".

Use of this technology permitted TZ significantly increase production and achieve substantial economic effect without capital investments or use of the expensive materials.

We will only briefly describe these phases here. More detailed information about these models will be presented in a separate presentation at this conference.

Technology based on concept of "Optimal heat" supports two levels of calculations.

First level - control of the BOF heat

The main objective of the first level - obtaining the given technological parameters of BOF heat, the reproducibility of the dynamics of the process from heat to heat, better reflecting the impact of the controlled parameters of the BOF process. The task is achieved through the application of technological improvements and mathematical models of the BOF process. Change is expected (operative updating) of the model parameters. Feedback is provided (operational) through actual results BOF heat and results of dynamic optimization. The correction of the required characteristics after heat and compared with estimates and actual results allows eliminating the effects uncontrolled factors and man.

Produced results allow to:

- stabilize the thermal balance of the heat, achieve optimal temperature at turndown after the main blow;
- provide the required regime of the heat, optimal chemical composition of slag during the blow;
- achieve aimed chemical composition of steel;
- reduce the number of corrective operations during the heat;
- reduce the cycle of the heat.

As a result of this approach, the BOF shop was able to implement the Technology of quick tap and significantly increase number of heats that do not await the chemical analysis.

Implementation of heats in one-stage process (Figure 7)

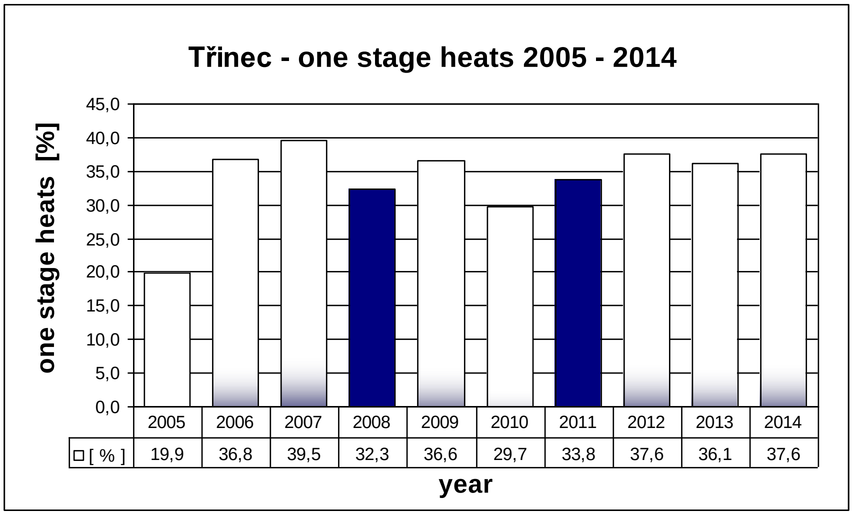


Fig. 7 Share of heats using one-stage approach

Second level - dynamic control

The main task of the second level - adjustment of local deviations from a given mode of operating the heat (stabilization of the dynamics of the technological process) and correction of parameters of the models of the first level control. The problem is solved at the expense of short-term adjustments (short-term changes) blowing and flux patterns (change the position of the lance and the intensity of the blow and redistribution of additives fluxes during blow).

Feedback is to use the results of dynamics of changes in the composition of exhaust gas of BOF and actual results BOF heat, which allows to increase the accuracy of the operations to achieve parameters of “optimal heat".

An important role at this level of control is the definition of "special" points during the blow. For example, sharp increase of content of CO2 in the late stages of heat, also beginning of intensive decarburization BOF baths, etc. The use of "special" points “sharp increase of content of CO2 in the late stages of heat also beginning of intensive decarburization BOF baths, clarified the calculation of the amount of oxygen in the final period, necessary to achieve a given carbon content in the metal and temperature of the bath without intermediate measurement measuring lance along the main blowing.

The implementation of the model takes into account the time lag of factual information and time of inertia (constant time) processes in BOF bath and also controlled conditions of the systems, as they have their own dynamic characteristics (for example, transport lag time for analysis BOF exhaust gas).

Use of dynamic (algorithm operating) optimization allows to:

- reduce loses of slag sloping during blow;
- provide required slag regime during the heat;
- reduce oxidation of slag and steel;
- increase the degree of control over the process, timely react to disturbances in the control systems;
- tune parameters of the first level of control.

Joint use of two-level optimizations allows to:

- achieve jointly prescribed carbon and temperature of steel at turndown;

- reduce the costs of lining maintenance;
- increase yield of liquid steel;
- increase production of steel.

The introduction of the second level control Z-BOP model allowed to achieve economic effect in steel production in stage 3 – additional 2.5 USD/t, in stage 4 – additional 2.0 USD/t.

Conclusions

Over the last 15 years, ZapTech implemented many technologies which allowed company TZ to complete full modernization of the production, expand the assortment of produced steel, (significantly more complicated types), increase quality of steel and reduce the cost of steel.

As a result of its cooperation with ZapTech, TZ was able to:

- increase steel production;
- increase yield of liquid steel;
- increase share of scrap in metallic charge;
- improve lining life of the BOF lining;
- reduce by 2.8x unit costs of the lining;
- economic effect from the implementation of ZapTech technologies exceeds 10.0 USD/t

Achievement of the above listed indicators was possible from the following actions:

- basic Z-BOP model with Z-BOP basic technologies;
- use of the carbon-content materials;
- scrap preheating in the BOF - implementation of the flexible technologies which allow effectively conduct process in the conditions of hot metal's shortages or excess;
- production in industrial volumes of magnesia sinter flux;
- implementation of one-stage heats and quick tap;
- Implementation of supported two-level model of control of BOF heat.