Automated Control System for BOF Steel Making in Třinecké železárny

Vladislav Jakubik, **Zdeněk Jurčik**, **Wieslaw Malysz**, **Jiří Cupek**, TŘINECKÉ ŽELEZÁRNY, a.s. , Průmyslová 1000, 73961 Třinec, Czech Republic, **Jaroslav Opletal**, **Sergey Chernyavskiy**, ZapTech Corporation, 3575 Piedmont Road NE, Bldg 15 Suite 710, Atlanta GA 30305, USA
Vladislav.Jakubik@trz.cz, Zdenek.Jurcik@trz.cz, Veslav.Malysz@trz.cz, Jiri.Cupek@trz.cz, Jaroslav.Opletal@trz.cz, sergey.chernyavskiy@hotmail.com,

The presentation discusses main principles of building system of controlling converter's heat with use of ZapTech's mathematical model. Described are the problems of implementation of controlling algorithms and future prospects of automated system in the conditions of converter production. Provided are the main provisions of algorithms of control of converter's heat, analysis and evaluation of the data, which allow to optimize the technology of steel production , reduce the cost of exploitation of the automated system and reduce the cost production of steel.

1. Introduction

Starting in 1998, BOF shop of TŘINECKÉ ŽELEZÁRNY, a.s. (TŽ) together with ZapTech Corporation implemented ZapTech proprietary technologies, so-called "Z-BOP Technologies" designed to improve efficiency and reduce cost of steel production. All implemented technologies are supported mathematical model and algorithms of control, so-called "Z-BOP model". It was implemented into existing control system of the BOF shop and required minimal changes.

The Z-BOP Technologies are protected US and international patents and enables to:

- Manage ratio of scrap/hot metal, in accordance with the requirement of the steelmaking process and their prices.
- Use the optimal ratio for flux materials, fuel and new materials (sinter fluxes, etc.).
- Control blow and flux regimes for BOF heat.
- Get specified (optimal) parameters of heat at the end of the main blow of BOF heat.
- Consistently manage BOF heat and operations between heats for lining of converter by maintaining the optimal configuration of the furnace and the resistance of the lining and bottom stirring elements.

The BOF shop TŽ is one of the best equipped steel plant in Europe operated 2 185-ton converters with bottom blowing with inert gas (argon or nitrogen). The control system of BOF shop consists of 2 levels: level 1 - control level, level 2 - information level. The exchange of information between levels is done through GCOM OPC server.

The structure of the control system has based on the ABB System Advant.5.1 800xA and on the platform HP AlphaServer DS25 with HP OpenVMS 7.3 operating system. It is presented in Figure 1.

Characteristics of software support for Z-BOP model has based of:

- Programming language: C++ (integrated).
- User Interface: Magic (by Magic Software Enterprises).
- Database: Oracle RDB (by Oracle Corporation).
- Exchange data between the Z-BOP model and information system of BOF shop: mailbox
- Multitasking: sequential.

All implemented technologies are supported by Z-BOP model, which provides two-level control and automation of the technology of steel production.

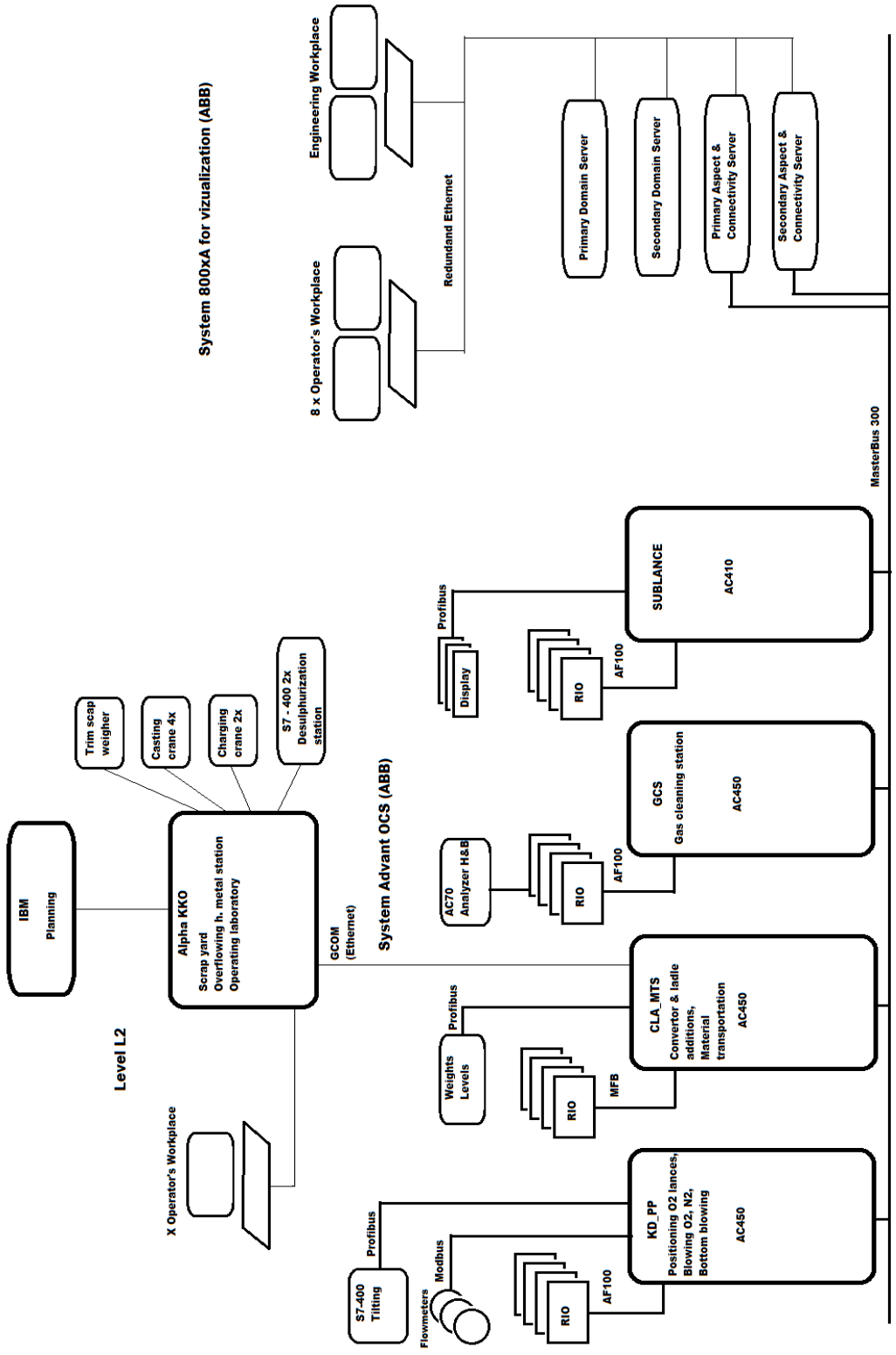

Fig. 1 Structure of control system of BOF shop

2. Mathematical models and algorithms of control of the first level

Mathematical model and algorithms are presented in two-level system: 1st level - static, 2nd level – dynamic.

The first level of control includes mathematical model and algorithms of control of BOF heat, which support the implementation of ZapTech's Z-BOP technology. The implementation was realized in several stages in cooperation with TŽ IT specialists:

Stage 1: (1999)
- Z-BOP model of calculation of metallic charge, fluxes, and oxygen for heat
- Use of carbon-containing materials to increase share of scrap in metallic charge of BOF heat

Stage 2: (1999-2002)
- Scrap preheating in the BOF
- Use of new MgO material (MgO sinter flux) to replace burnt dolomite
- Correction of blow and flux patterns of the heat to prevent sloping (model prediction for sloping)
- Support of required configuration of the BOF and improving lining life of elements of bottom stirring (slag blow by nitrogen)

Stage 3: (2003-2005)
- Transition to one-stage technology of steel production from the previous two-stage technology
- Implemented technology Quick-Tap (without waiting for analysis)

Implementation of the algorithms and models has many features:
- Modernization of the information system of BOF shop was executed at the same time as the implementation of the control algorithms and models; mutual impact and joint development allowed to increase the effectiveness of operations, reduce the time required for implementation and conduct the training of the technological staff together with the implementation;
- Close integration of the information system of the BOF shop and Z-BOP model increased quality of information for calculations;
- Close integration of the information system of the BOF shop and Z-BOP model allowed implementing the full set of algorithms of control of BOF heat and implementing dynamic control of BOF heat (second level of control system).

Complex use of the technologies and computer support increased flexibility of the steel production technology in the BOF shop, which allowed to:
- Increase production of the BOF shop;
- Solve shortage problem of hot metal during the maintenance of blast furnace;
- Provide full automation of the steel making process;
- Provide stable results regardless of the changing conditions for steel production: changes in prices for metallic charge materials, changes in quality of materials, changes in production conditions.

3. Mathematical models and algorithms of controls of the second level:

After completion of the implementation and installation of Z-BOP model's first level of control, in 2006-2014 the second level of control (dynamic control) was implemented, based on the concept of "optimal heat".

The technology, based on concept of the "optimal heat", is the most effective tool for generating maximum profit in the conditions of modern production. It applied on the basis of existing system of control of the technological process in the BOF shop and does not require expenses for new materials or new technological equipment.

In ZapTech's software realized algorithms of automatic control and improvement of the technologies of BOF heat, solves problems of process control, its adaptation and optimization of the Converter production in general.

Technology based on concept of "optimal heat" supports two levels of calculations:

3.1 First level of calculations: - optimization of static level of control of BOF heat

The main task of the first level - structural and parametric optimization of the Z-BOP model for attaining required technological parameters of the heat, reproducibility of dynamic processes from heat to heat, more complete account of the influences of controlled parameters of BOF process. The task is achieved by the use of technological improvements and mathematical model of BOF process. The changes are expected (operational refinement) of parameters of the model (object of control). Feedback is functioning through actual results of the BOF heat and results of work of dynamic optimization. The correction of the required controls after the completion of heat and their comparison with the predicted results allows avoiding the effects of 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.

3.2 Second level of calculations: - dynamic control

The main task of the second level is correction of local deviations from the required regime of the heat (stabilization of the dynamics of technological process) and fine-tuning of the parameters of the models with the first level of control. The problem is solved at the expense of short-term changes the position of the lance and the intensity of the blow and redistribution of additives fluxes during blow. Feedback is functioning through use of results of gas analysis of the BOF exhaust gases and actual results of BOF heat in order to improve the precision of the performance of offered technology of "optimal heat".

Important role at this level is played by the defined "special" points during main blow of BOF heat. For example, changes in the concentration of carbon, identification of the start of intense decarburization of BOF bath, sharp increase of probability of slag sloping, etc. The use of "special" point of "changes in the concentration of carbon" allows refining the calculation of amount of oxygen needed in the final stage to achieve aimed content of carbon in the steel and temperature of the BOF bath without intermediate measuring during blow.

Important role is played by the time lag of actual information and time inertia (constant time) of the processes in BOF bath. It is also important to monitor the conditions of the controlling system since it has its own dynamic characteristics (for example, transport time lag for the analysis of the BOF exhaust gas), disregard of which may lead to the mixed results for parameters of technological process and as a result misbalance of the entire control system.

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.

Implementation of the technology based on the concept of "optimal heat" was done in two phases:

Phase 1: Analysis of BOF exhaust gases and determining the transitional concentration of carbon, optimization of the final period of main blow of BOF heat, implementation of the technology of one-stage blow with or without waiting for the analysis, including without intermediate measure during the main blow of BOF heat.

Phase 2: Implementation of algorithms of suppressing sloping, reduction of slag oxidation through correction of blow and flux regimes during the main blow of BOF heat.

Implementation of dynamic control based on the concept of "optimal heat" allows to:
- Increase production of the BOF shop;
- Reduce oxidation of the BOF slag and steel;
- Improve stability of the process;
- Reduce the cycle of the heat;
- Increase yield of liquid steel.

4. Future prospects for further development

After the finishing of period of active adjustments to the software of the control system, and because of the planned modernization of the equipment of the control system, it was proposed to modernize the existing system of control of BOF heat. It should be noted that such modernization will not impact the calculating algorithms that are part of the ACS (automated control system). The main changes will be in modules of exchange data and organization of calculations.

The goals of modernization of the ACS are:
- Create new user's interface without use of Magic program (by Magic Software Enterprises);
- Execution of additional requirements of technological personnel to expand the functionality of the automated control systems;
- Full satisfaction the demand of IT specialists for expanding functionality;
- Reduce computation load from the control level (ABB) and reduce data exchange.

The conditions for modernization of the ACS are:
- Transfer of the functions and features of information system BOF shop (including the model of BOF heat) to the new platform HP OpenVMS Industry Standard 64 Operating System version V8.4, only using the available software capabilities;
- Removal of identified during the exploitation for period from 1998 to 2014 deficiencies of the existing control system BOF shop.

Proposed software architecture:
- Use of three-tier architecture for building applications (client – server computing (system core) – server of database);
- Use of component model for implementing applications;
- Use of shared memory;
- Use of multithreaded calculations;
- Use of multiple levels of data storage.

Structural architecture is described in Figure 2.

Client – level includes:
- Implementation of the applications for the client in any programming environment (by Microsoft, Visual Studio, Borland, etc).
- The use of XML or another media for data exchange;
- Transfer of all computation to the computing server.
- Use of local cache for acceleration of access to data.

Computing server – level includes:
- The creation of the components:
  1) Component interaction with remote systems (client, controller, other programs): use of modern technologies of information exchange, compatibility with existing technologies;
  2) Component interaction with databases: Oracle RDB (for Alpha or Itanium); MS SQL Server, Oracle, Firebird as third-party database, etc;
  3) Component interaction with the Z-BOP model of BOF heat: issue of request for the calculation and handling of response;

4) Components of control shared memory: fast memory for the Z-BOP model of BOF heat; keep the data in the database;
5) Component multitasking of computations: managing task and memory.

- Defining interface for each component.

Database Server – level includes:

- Establishing of database structure for various functions of the system. Database for different platforms: OpenVMS, MS Windows, and Linux.
- Organization of table space: archive data, actual data, data for modeling, etc.

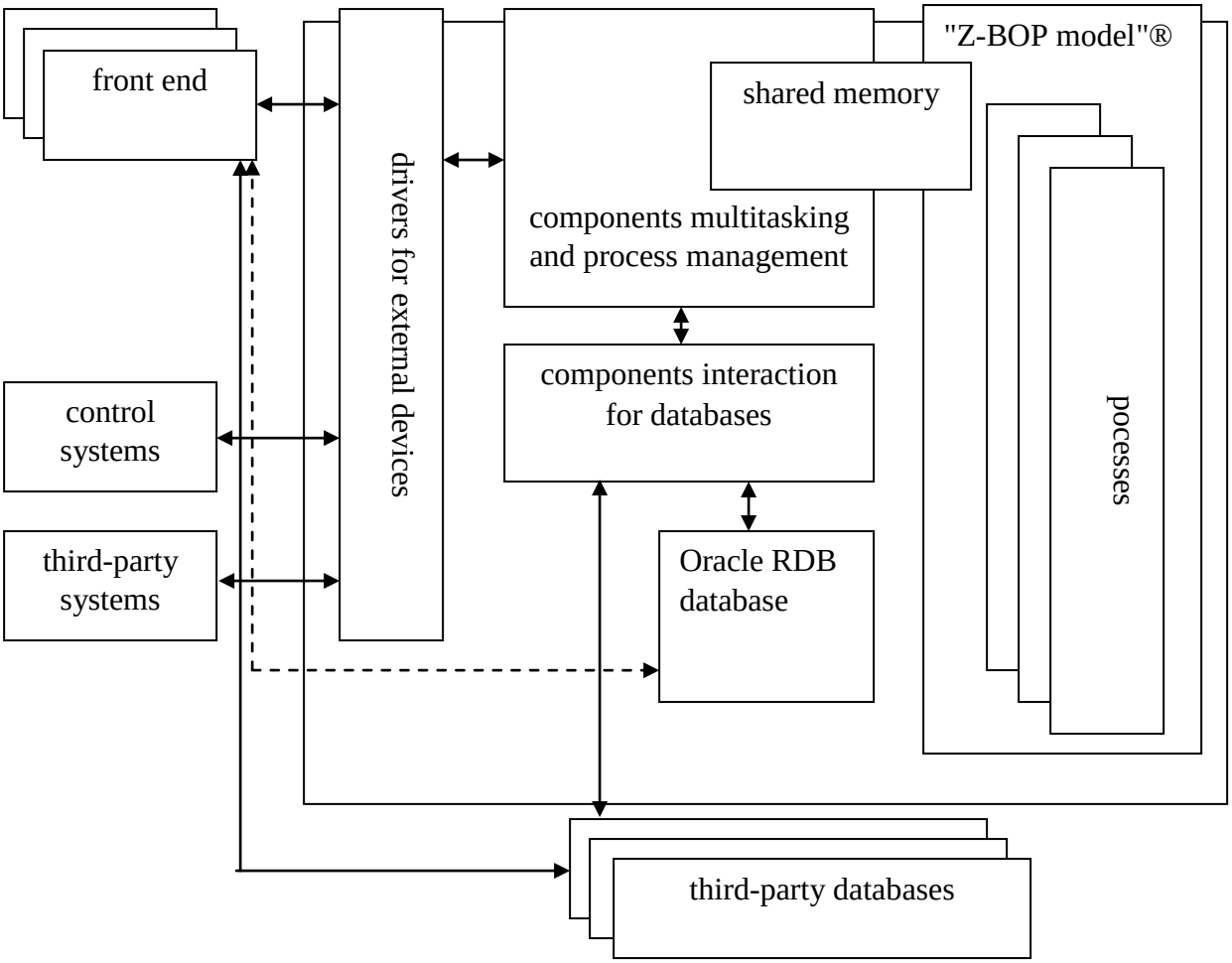

Fig. 2 Structural architecture

A benefit of new architecture includes itself**:**

- Reduces costs for software maintenance and use;
- Reduces business risks related to malfunctioning of separate parts of system;
- Provides real multitasking of the calculation;
- Provides increase in speed of actions;
- Allows using additional tools for optimization of the process and modeling for BOF heat.

New opportunities are**:**

- Fast adjustment and commissioning of the changes;
- Model computations for single heats and series of heats, comparison of calculations as part of the control system instead of using outside tools;
- Connecting of practically unlimited quantity of users, ease of the access;

- Standardization of the processes and program interfaces;
- Protection management system from unqualified and unauthorized access.

5. Conclusions

Over the last 15 years, ZapTech implemented number of technologies, which allowed company TŽ 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.

Automated control system and ZapTech technologies include algorithms of control and Z-BOP model, which provides support of all technologies of BOF heat, was implemented and are being used in the BOF shop.
Economic effect from the use of Z-BOP technologies and Z-BOP model:

	Stage 1	Stage 2	Stage 3
Level 1	1.5-2 $/ton	1.5-7 $/ton	2.5 $/ton
Level 2	2 $/ton		

The proposed algorithms of management and changes in the functioning of the management system due to modernization allow increasing the flexibility and efficiency, performance and reliability, reduce the costs of IT. Implementation of proposal creates the opportunity to develop the technology on a higher level, and is used the additional features of the new equipment in the transition from platform HP Alpha (AlphaServer) on HP Intel Itanium and to optimize the interaction of informational and control levels, reducing the load on the controlling level.