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COMPUTER-AIDED DESIGN SYSTEM OF TECHNOLOGICAL STEELMAKING PROCESS

Разработана система автоматизированного проектирования технологического процесса выплавки стали. Остовом продукта являются теоретические и практические достижения в области сталеварения реализованные в виде моделей и алгоритмов, собранные в программном комплексе с интуитивно понятным и дружественном интерфейсе. На примере проектирования технологического процесса в кислородном конвертере показаны основные функции САПР с помощью которых опытный технолог в кратчайшие сроки может разработать, просчитать и оценить любые нововведения касающиеся начинки сталеплавильного агрегата, использования новых материалов и энергоносителей, режимов их ввода и т.д. Наличие «визуального» проектирования дает возможность получать решения, которые учитывают как формализуемые, так и неформализуемые критерии. В целом это дает существенный выигрыш как по времени так и по затратам.

Ключевые слова: кислородный конвертер, моделирование, технологический процесс, проектирование, прогаммный комплекс, САПР ТП.

Розроблено систему автоматизованого проектування технологічного процесу виплавки сталі. Остовом продукту є теоретичні та практичні досягнення в галузі сталеваріння, які реалізовані у вигляді моделей і алгоритмів, зібрані в програмному комплексі з інтуїтивно зрозумілим і дружнім інтерфейсі . На прикладі проектування технологічного процесу в кисневому конвертері показані основні функції САПР за допомогою яких досвідчений технолог в найкоротші терміни може розробити, прорахувати і оцінити будь-які нововведення, які стосуються начинки сталеплавильного агрегату, використання нових матеріалів та енергоносіїв , режимів їх введення тощо. Наявність «візуального» проектування дає можливість отримувати рішення з урахуванням різних критеріїв, котрі або формалізуються або неформалізуються. В цілому це дає суттєвий виграш як у часі так і за витратами.

Ключові слова: кисневий конвертер, моделювання, технологічний процес, проектування, прогамний комплекс, САПР ТП.

A system for computer-aided design of technological steelmaking process is developed. The frame of the product is theoretical and practical achievements in steelmaking area which are implemented in the form of models and algorithms collected in the software package with an intuitive and user-friendly interface. On the example of the design of technological process in oxygen – blown vessel the basic functions of CAD are shown, using which an experienced technologist in the shortest possible time may develop, calculate and evaluate all kinds of innovations that concern the filling of steelmaking unit, the use of new materials and energy, their entry modes, etc. The presence of “visual” design allows obtaining solutions that take into account formalized and non - formalized criteria. In general this gives a considerable gain both in time and cost.

Keywords: BOF, modeling, process, design, software system, CAD TP.

Every year Computer-aided design systems of technological process (CAD TP) find application in various branches of industry [1-3]. This is due to the fact that the development and usage of CAD TP reduces creation and

operation charges of the designed TP, increases labor productivity of designers and reduces the volume of project documentation.

CAD TP are widespread in engineering [1,3], in metallurgy, similar systems are presented in the form of simulators [5] or simulation models [6], which are intended for the prediction and research issues.

Labor input and the cost of the technological process' design is growing from year to year, which is caused by the continuous complexity of steelmaking facilities constructions and equipment that is used, increasing requirements to the metal quality, manufacturing flexibility and time of development melting technology of any brand. There is a need for high quality technological processes design, which means, that the product received according to the developed technology, should be qualified by the technologist and have minimum value.

It is necessary to develop various options for the TP to find a rational one. An evaluation, which was carried out [4], showed that number of technological process options can reach thousands even if it has minimal set of options. Considerable computational difficulties and time-consuming for manual solve of complex equations makes the task of designing such amount of options in the allotted time impossible. Therefore, the development of technological process is subjective and the quality of engineered technological process depends on the technologist's experience and skills [3].

Thus, one of the ways to improve the development process of steelmaking is automation of TP design. For this purpose the aim of this paper is to create a tool which can help the engineer to develop and evaluate technological process of given steel grade smelting, evaluate the impact of equipment modernization, materials replacement on technological and economic indexes.

The main CAD features as projection system is to receive finished design decisions and corresponding project documents [7]. For this purpose CAD should consist of software which performs the appropriate function: technical, mathematical, computer, information, linguistic, methodological and organizational. As the determiner mathematical software can be highlighted - as it is a set of mathematical methods, models and algorithms of designing; and information software or the database that contains the description of the typical design solutions, reference information, etc. presented in the required form.

In terms of mathematical software CAD TP must have a powerful software package, where mathematical models meet the following requirements: universality, adequacy, accuracy, economy. Therefore, a deterministic process model should be in the basis of CAD TP which is particularly effective in the technological process development and in solving operational tasks in melting management. It helps to solve problems that both refer to structural optimization, which is not available in systems based on formal statistical models, and usual parametric optimization, because it gives possibilities to solve them analytically.

CAD TP data collection should fully ensure the implementation of the informational needs of all compound components of CAD, mainly mathematical software.

Submitted requirements are implemented in the software complex “Designing Melt” [8]. All the algorithms and calculations of the program are based on the thermodynamic model of the condensed phase [9], which allows even without statistical “binding” to solve a wide range of practical tasks. This allows to do: thermodynamic calculation of balance in multicomponent heterogeneous system “metal - slag – gas”, calculation of partial pressures of all atomic and molecular components of the gas phase, integrated thermodynamic temperature calculation of system’s temperature based on enthalpy heat balance; computation of all integral and partial thermodynamic functions of the system components; keeping heat energy, temperature and aggregation state of materials.

In order to extend the capabilities of the thermodynamic calculation in equilibrium approximation a compensating element, which reflects the process in particular form, was introduced. The concept “reaction” zone was introduced by the authors in the presented model [10]. It follows from this model that any continuous process can be approximated by a set of temporal discrete segments and the shorter the duration of the process at each selected segment, the closer the approximation to continuously described processes. In this case, as the approximation criteria a quantity (mass) of a condensed phase, which comes into balance per unit time, was adopted.

The development of new technology involves the creation of smelting in time project, the coordination of the equipment modes, material input, the evaluation of changes in the basic melting parameters (chemical composition, mass and temperature of fusion products) in time, etc. To build the in time smelting project design principles, which are stated in the article, were used [11].

Design is a complex process that combines procedures of structural technology synthesis, the choice of elements parameters, results and decision-making analysis. On the example of the basic – oxygen steelmaking process, we can consider available design methods which are implemented in the proposed CAD TP. There are two basic approaches to the TP design: synthesis method and the method of analog use. The synthesis method consists of two stages. The first stage of design is the structural synthesis for a fundamental decisions generation. It is difficult to form task, so it can be solved interactively between CAD and operators (technologist). In the proposed computer-aided design system the process begins with the preset of the technological process duration and steps of design (modeling and visualization) (fig. 1).

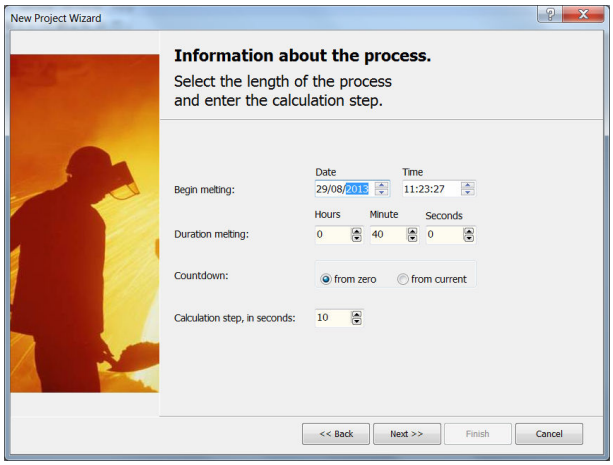

Fig. 1. – Temporal design parameters

Combination of information required to perform computer-aided design and presented in a given form [3] represents information support system. The main part of the data collection is a database (fig. 2), which contains the physical, chemical and thermal characteristics of the periodic table of the elements, the equilibrium constant in the condensed and gas phases, Wagner coupling parameters, available materials and their composition, available steel brands and their composition, tasks for steel melting (processing), etc. In the process of CAD operation, the database is updated, corrected and, moreover, its protection from inappropriate changes is carried out.

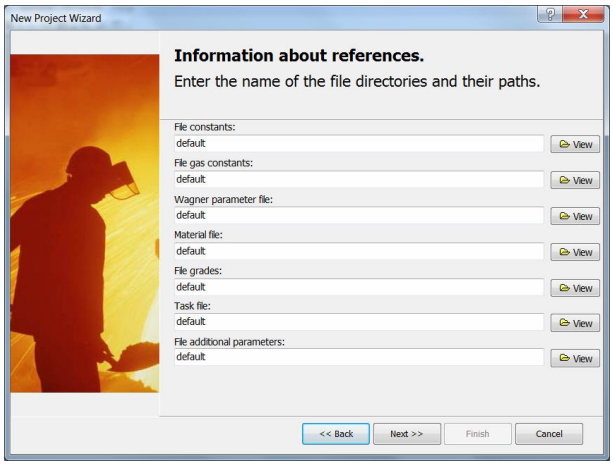

Fig. 2. – CAD data collection

After that a steelmaking unit, where the planned smelting process or steel processing (which determines the method of smelting) is planned to be run, is chosen (fig. 3). Steelmaking unit characteristics are assigned: the geometric dimensions of internal and external space; nominal charge weight, lining weight and material.

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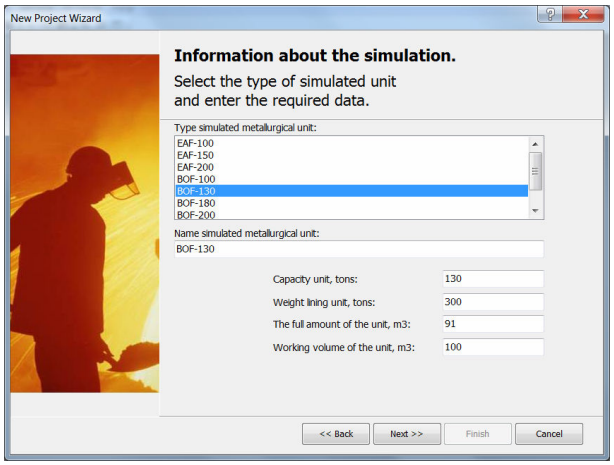

Fig.3. – Steelmaking unit features

At the next step of structural synthesis equipment, which the steelmaking unit will be provided with, is selected (fig. 4). A wide range of modern steelmaking units’ equipment is represented in the program database. If the necessary equipment is missing in the accessible list, you can just select the similar. In the future, this equipment can be edited and stored in the database for further use.

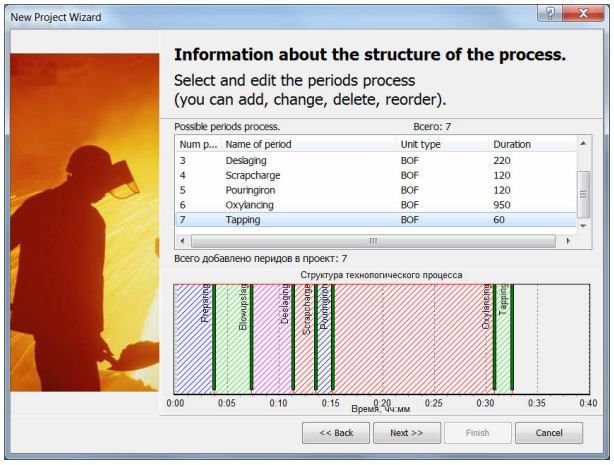

Fig. 4. – Steelmaking unit equipment

The final step of the procedure is structural synthesis of the technological process: technological periods of process are selected; sequenced; preliminary duration of each technological period of melting and processing is set (fig. 5). Most of the periods are contained in the database of the system, and the technologist can just choose the necessary one and indicate its temporal characteristics.

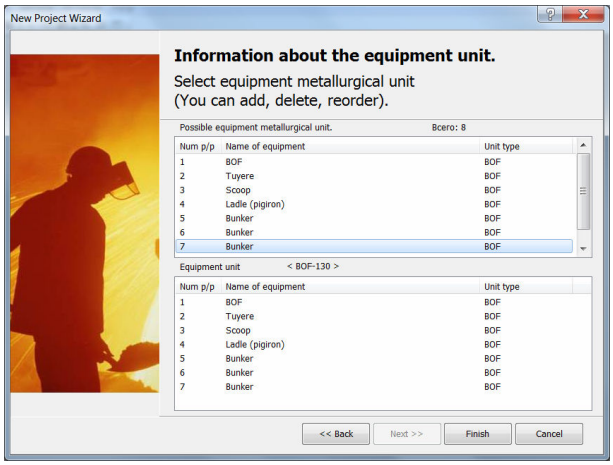

Fig. 5. – Description of the technological process structure

During the re-equipment of the unit, “on default” modes, input materials or energy resources are added. As a result, we obtain a virtual steelmaking unit, which corresponds to its real counterpart (fig. 6).

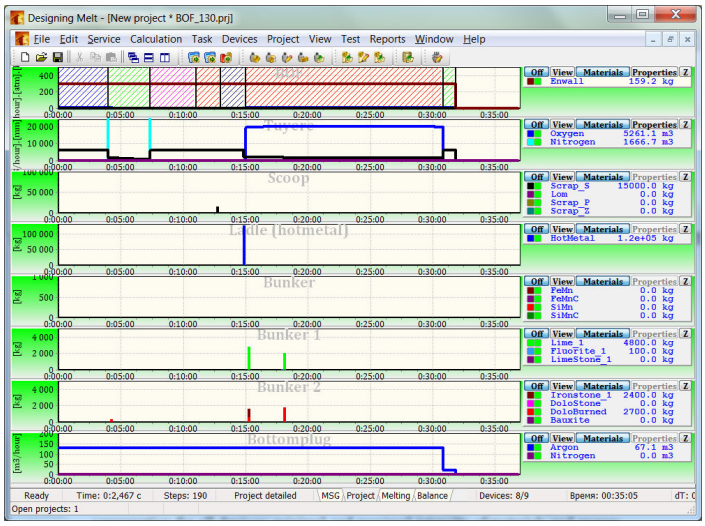

Fig. 6. – Virtual steelmaking unit

Then, further verification of the design solution is performed, it is necessary to set or calculate the parameters values, i.e. to do a parametric synthesis.

At this stage of design for each period end criteria are set (on temperature, time, material or energy consumption). The final technological process parameters and initial conditions are set: the chemical composition of the metal and slag, system’s temperature; mass phase, the state of the lining.

Additional restrictions on the use of materials and equipment are imposed: availability at the storehouse or melting limit; if there are several devices than overall consumption for all devices; minimal and maximal intensity of materials and energy consumption.

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If necessary, models of metal slag, gas, temperature system, and the kinetics of the process calculations are chosen. It is also possible to edit technological process by changing modes of material input, by changing temporal periods of materials output (scrap metal input), by changing the duration of the individual periods and the whole melting , adding or removing materials. It is also possible to add, delete and edit the used equipment and process periods. The end of the process creation is an imitation of melting input according to the project.

According to the set levels of materials and energy input, and taking into account the full material and energy balances, thermodynamic calculations and kinetic correction (entry speed of reactants, dissolution, speed of the date averaging according to chemical composition and temperature), melting with the pre–programed time steps (rather short) is simulated. The results of parametric synthesis are (fig. 7):

- Calculation of the metal, slag and gas chemical composition during the process;
- Calculation of the metal, slag and gas mass during the process;
- Calculation of the system temperature and average temperature in accordance with the unfused batch and lining temperature;
- Calculation of phase interaction kinetics;
- Calculation of material and heat balance.

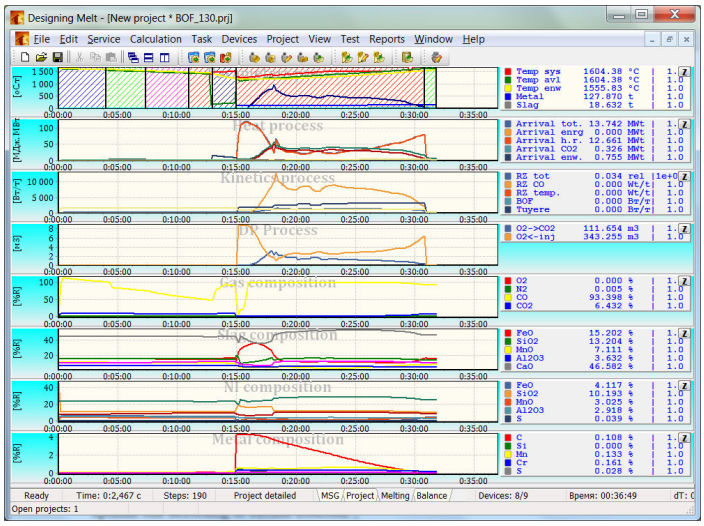

Fig. 7. – Results of parametric technological process synthesis

If the results of the project solution analysis (fig. 7) are considered uncompleted, then begins the process of successive approximations to an acceptable version of the draft, the so-called parametric optimization - the determination of the best values of a technical object (system) of known structure parameters.

Very often in order to improve project it is more convenient to vary elements quantity values, i.e., to use parametric synthesis based on

multivariate analysis. The task of parametric synthesis can be formulated as the problem of determination of elements parameters, which meet the requirements of the technological assignment on a constant structure of the designed object.

In CAD parametric synthesis procedures are implemented either by man in the process of multivariate analysis (interactive mode) or on the basis of formal optimization methods (in automatic mode).

In the first case, the calculation takes place on modes set by operator without changing the duration of the period and operations, without changing mass and materials and energy input modes, without changing the start and the end of the operations. This mode allows you to create a huge number of projects and to choose optimal one according to certain criterion.

In the second case, the proposed CAD TP optimizes technological process taking into account final set-up parameters (temperature and chemical composition of the metal and slag, phases weight), and imposed restrictions on the equipment operation and materials and energy input. Optimization is carried at process cost, which allows producing metal of the specific chemical composition and temperature of the specified time. When there are no solutions, the restrictions which were imposed on the process, can be removed according to the set priority and recalculated.

When calculations are completed CAD TP forms the documentation of the technological process in the smelting process or steel processing chart form, and in the form of a smelting passport with the register of major events. Such documents are well known to technologists and are similar to those which are used in enterprises equipped with ACS TP.

With the help of this method it is possible to design TP for a wide range of steel processes and nomenclature. At the same time it should be noted that the quality of solutions in the proposed CAD TP, their effectiveness depends on the skills of the staff (technologist, operator).

While using CAD TP various technological steel smelting and processing solutions of individual steel grades and groups of grades are accumulated, individual modes of equipment, materials and energy inputs are kept. Therefore, it is possible to design on base of use of analogues method. The main point of this method is in the reuse of developed technological solutions.

While creating a new project, the operator can use the existing technological processes library and select as the prototype the closest to the one which is being developed. The criteria for selection are:

- Steelmaking unit for smelting or steel processing;
- Method of smelting or steel processing;
- Final chemical composition of the steel or the intermediate product in unit.

Using this method the complete elimination of structural synthesis of the design object and the partial or complete exclusion of parametric synthesis of the previously described method of design is possible. The process of the

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technological design process is similar to the process discussed earlier. If necessary, the technological process can be changed by repeating the first two steps: TP convert by eliminating unnecessary or adding new structural elements of TP and edit parameter values which are required for the verification of design solution.

As we see, the method of using the analogue is a special case of the synthesis method, which allows significantly simplify the process of project creating the and search for the optimal solution.

Conclusions

Developed CAD TP represents a synthesis of the latest achievements in theory and practice of steelmaking which are gathered in a compact software product with a friendly intuitive measuring interface.

Minimal use of empirical relationships, which are relevant to a particular steelmaking unit, while developing computer-aided design systems allow you to model the most of the existing steelmaking facilities and (converter , electric arc furnace , ladle furnace, vacuum degasser), treat them individually and as a single technological complex.

The presence of the deterministic approach in the mathematical description of technological processes allows assessing all of the relevant process characteristics without changing the structure of the model.

Created CAD TP is quite functional and it reduces the cost and complexity of TP developing; improves the quality of the designed processes; has the tools to adapt to the changing production conditions, and makes developers labor more creative.

In CAD TP “visual” design process is implemented. The user can set the values of parameters under control, inspect the allowable change of these parameters and entire output criteria. As a result we get a set of acceptable solutions, which are considered both as formalized and non-formalized criteria.

Introduced software package can be used in the learning process and it gives students an opportunity to feel as steelmakers, who has the opportunity to make mistakes.

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