PROGRAM COMPLEX OF THE MATH MODELS OF THE IRON ORE PELLET METALLIZATION PROCESS FOR DRI PLANTS

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At the end of the previous century the math models for kinetic-and-dynamic and balance calculations of DRI have been created for the first time ever in the course of Russian technology development of iron ore pellets in the shaft furnace as well as for the design of industrial plants of DRI [1]. Consequently, those models were being adopted, particularly, for improvement of the technology and thermal modes of the active metallization plants of the Oskolsky electrical and metallurgical plant (“OEMK”). The brief description of these models is given below.

The balance model of metallization plant and program complex “Automatic working station of the technologist” have been developed after start up of metallization unit of the “OEMK” in order to gather the production and process data of metallization plant and perform a necessary thermotechnical calculations[2]. An analysis of metallization plant operation had been conducted in this regard, along with the ratio between technical and economical values, quality of raw materials and metaled product with their technological parameters. The operation reports of all metallization plant units have been compiled on the basis of obtained results using the methods of math statistics.

The developed technique is based on the program complex of material and power balances of the shaft furnace and reformer. The physical and chemical transformations peculiar for metallization technology have been considered in the calculation. These transformations proceed during interaction between gas and furnace charge and combustion and/or reforming of the fuel.

-preheating, reduction, carbonization and cooling of furnace charge (considering dust entrainment);

-gasification of oxygen, carbon and furnace charge moisture;

-evaporation and condensation of moisture;

-pyrolysis, conversion (or formation) of hydrocarbons;

-oxidation of combustible components of fuel under air excess;

-heat transfer through the walls of instruments and gas ducts of metallization plant to ambient.

The temperature dependence of the heat and physical characteristics of the gas and furnace charge were included in the model to enhance a precision of the calculation, along with dependence of gas composition on the parameters of condition during thermodynamic equilibrium and water saturation conditions. The experimental data of heat losses obtained in winter and summer period of metallization plant operation are also included. The data of the previously created database are being used as the initial parameters, with the regular uploading of information derived from daily reports about the operation of metallization machine modules.

The proposed technique is different from similar developments with its improved structure with elements of expert system and metering skid of heat losses. As a result, on the basis of partially reliable data being adapted, we can get a rather trustworthy and balanced result. An adaptation procedure is carried out with expert being involved, who possessed a positive technological experience and familiar with production features. The calculated results of this technique are as follows: adjusted parameters of material flows, complex values of shaft furnace and reformer and material and power balance compiled with specified tolerance.

The kinetic- and dynamic model can be used as an addition to balance calculations of “Automatic working station of technologist” for predictive modelling of a various operating modes of metallization plant and process control of the DRI. This model allows for calculation of real process dynamics of the pellets metallization within a shaft furnace volume. This might expand a search and estimated development of the new operation modes of metallization plant (including gas and oxygen conversion, in-furnace conversion and decomposition of hydrocarbons in the layer of sponge iron) in order to increase a production and improve the metallized product.

Kinetic-and-dynamic model («Model of shaft furnace») comprises the math description of the iron ore material metallization process (ore, pellets) and solution algorithms of the differential equation system of heat-and-mass transfer and gas dynamics, which could imitate all changes of the pellet parameters and reducing gas (mass consumption, temperature, pressure and chemical composition) in computer memory cells. This occurs in real time scale throughout the height and on the borders of shaft furnace zones [3].

Deterministic method of calculation is implemented in this model as the program complex, which might be used in computers as researcher instrument or technologist for analysis, predictive modelling and control of the pellet metallization process in shaft furnace.

While selecting the parameters of gas flows (consumption, temperature, composition) at the metallization zone inlet, parameters of pellets (granulometric and chemical compositions) taking into account the speed of furnace charge removal, the technologist could optimize an operation mode of a shaft furnace using this model in order to increase the production, quality improvement and reduction of power costs.

"Automatic working station" with database (from the operating panel of metallization plant) and "Model of shaft furnace" could be further used as an instrument named "Master wizard" for optimization of parameters and pellet metallization process control in the shaft furnace.

The charts of changes as to metallization process parameters within the height of the reduction zone in stationary mode (fig. 1) could be depicted as an example of practical application of these models, along with the charts of sponge iron dynamic parameters during control of shaft furnace operation control (from initial to quasi-stationary state, fig. 2).

Thus, the first phase of this calculation presents the results of the dynamics in the course of transition from initial parameters (Gm=80t/h, gas consumption Vg=132 th. m3/h, gas temperature Tg=950ºC) to increased productivity of the shaft furnace (up to the level of Gm=85t/h, and all other input parameters - const.). However, in this case it had been shown that the mentioned calculated control input will result in obvious exacerbation of sponge iron quality (due to decrease of metallization degree: from initial level ϕm=94% and up to the final one - 90% in 3 hours, fig. 2,a).

The specified production ramp up ΔGm≈6%) shall be compensated in order to improve a quality of the sponge iron by means of control input and in particular by changes of the reduction gas parameters (by consumption addition, ΔVg≈4% and temperature, ΔTg≈2%). In this regard the calculated pellet metallization degree would achieve a required level (ϕm=94%) in over 4 hours after beginning of these inputs (fig.2,b).

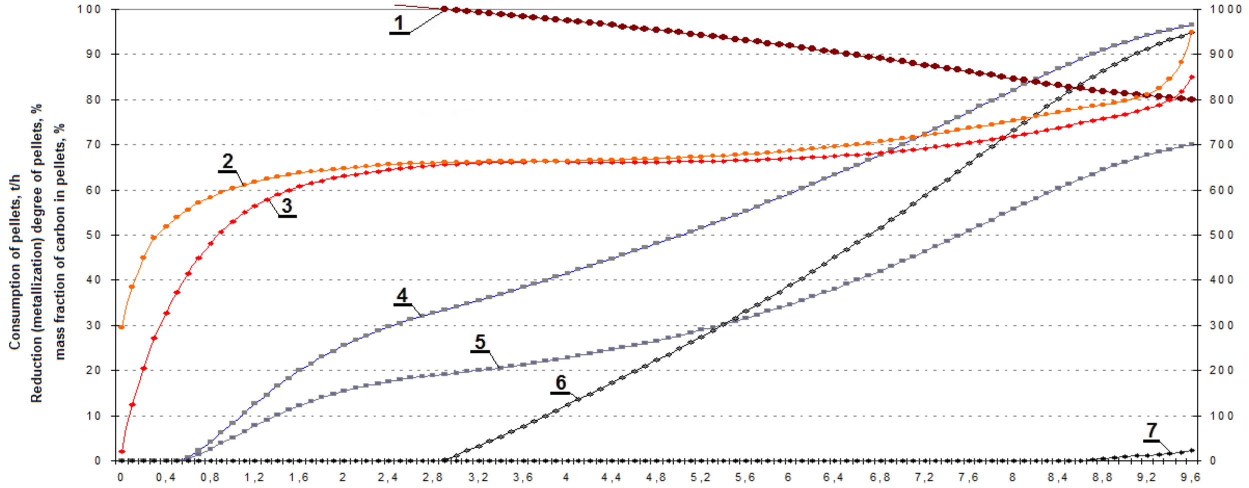
As it can be seen from the given charts which were obtained from the calculation example of the deterministic model «Model of shaft furnace» in totality with balance model "Automatic working station of technologist", the production of metallized product might be substantially ramped up by means of change of reduction gas parameters and it also might reduce its power costs providing a proper quality of sponge iron.

Conclusion

A balance model for DRI plants in a shaft furnace has been developed, with the inclusion of material and power balances of all basic metallization technology blocks (shaft furnace, reformer etc.). That model has been taken as a basis for program complex "Automatic working station" for analysis and optimization of the metallization plant operation modes of "OEMK" OJSC. The obtained results of heat engineering calculations were used in the refurbishment projects on the metallization plants and incorporated into operation.

Kinetic-and-dynamic model (heat-and-mass exchange and gas dynamics in the layer) could be additionally used for performance of operational analysis and predictive modelling of the DRI modes alongside with program complex "Automatic working station of technologist". The mentioned model imitates a dynamics of actual pellet metallization process in the shaft furnace «Model of shaft furnace». That option expands the development opportunities of the new metallization plant operation modes towards the production increase and improvement of the sponge iron quality.

Engineering of the system "Master wizard" is initially the part of the development of the mentioned models in the first phase and serves as an important instrument for optimization of parameters and pellet metallization process control. Subsequent development shall lead to creation of Automatic Process Control System (APCS) for production of the metallized product in the shaft furnaces.



Height of reduction zone (from grate bar), m

Fig. 1 Distribution of the metallization process parameters within height of the shaft furnace.

1 -pellet consumption, t/h; **2** -gas temperature Tg, ° c; **3** -temperature pellets Tm, c;
4 - reduction degree (general) ϕ,%; **5** - reduction degree by hydrogen ϕH_2, %;
6 - metallization degree of pellets ϕ_m,%; **7** - mass fraction of carbon in the pellets, %.

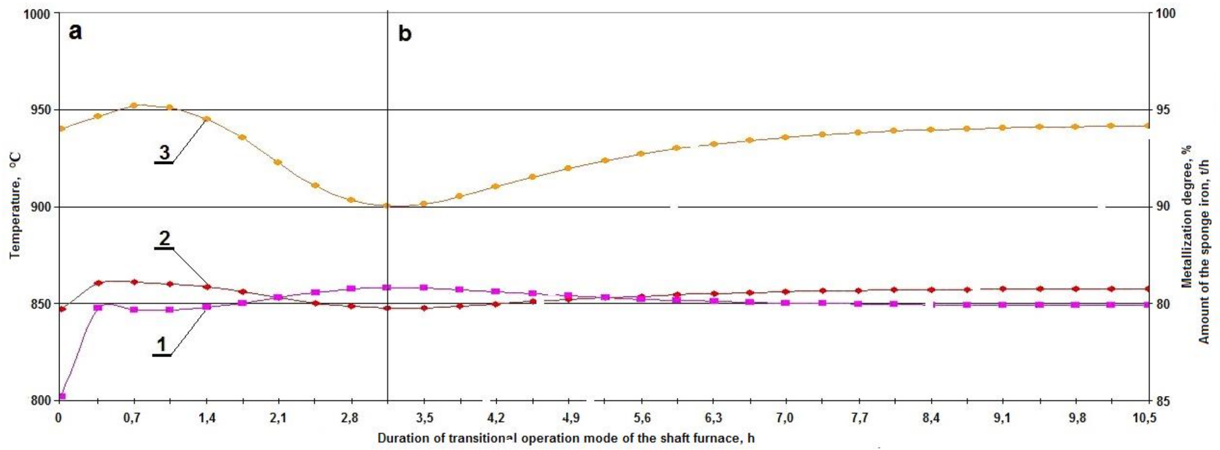


Fig. 2 Dynamics of the sponge iron parameters at the output of the shaft furnace reduction zone (in the lower zone limit - 9,6 m from grate bar):

a) during increase of sponge iron consumption ($\Delta Gm \approx 6\%$);
b) during increase of consumption ($\Delta Vg \approx 4\%$) and temperature ($\Delta Tg \approx 2\%$) of reduction gas.
1 - consumption Gm, t/h; **2** - temperature Tm,˚C; **3** - metallization degree of pellets ϕm, %.

The reference list

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Abstract

The program complex of balance model has been developed towards DRI plants ("Automated workstation of process engineer") along with kinetic-and-dynamic model of pellet metallization process in the shaft furnace ("Model of shaft furnace"). This complex is meant to be used for analysis and prediction of process operation, along with using it as the "Master's wizard" system being an important tool of Automatic Process Control System for optimization of the parameters and metallization operation control of the pellets in the shaft furnace.

The key terms used: *shaft furnace; metallization plant; direct reduction of iron (DRI); program complex, sponge iron.*