METHOD OF COMPLEX ESTIMATION OF MANGANESE RAW MATERIALS

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ABSTRACT

Decrease of manganese concentration in extracted ores, permanent rise of prices for rich ores and deminishing of their reserves is a common trend and accumulation of manganese-containing wastes is a worldwide problem. These factors in complex raise a problem of rational use of manganese raw materials of natural and industrial origin in ferro-alloys industry.

There are several solutions nowadays: involvement of non-standard and off-grade manganese raw materials in ferro-alloys production; development of reserves and resourses by exploration; production of ferro-alloys with a low content of basic element; optimization of charge composition by price for competitive production of standard alloys from mixture of expensive rich and cheap poor manganese raw materials.

It is proposed for ferro-alloys producers to use several principles for complex estimation of manganese raw materials: choosing the technology for ferro-alloys production/manganese raw materials processing; use of different methods of estimation of metallurgical value for ores and alternative manganese raw materials; maximum extraction of manganese from manganese-containing raw materials (ores, concentrates, slags, dusts, tails, etc.); assessment and monitoring of sources of manganese raw materials of natural and industrial origin.

Metallurgical value of manganese raw materials of different origin is of immense importance for decision-making when involving material into production chain. It is vital to estimate along with economical value (net cost, residual value) of involved materials, possible changes in engineering-and-economical performance on the basis of calculations or combination of calculations and experimental techniques for effective optimisation.

Method of complex estimation of manganese raw materials includes: thermodynamic calculations of possible reduction value of manganese from raw materials, which vary in chemical composition and require fluxes in FeMn and SiMn production; calculation of specific material and energy consumption for ferro-alloy production; selection of rational technology for raw materials processing (production of FeMn or SiMn); experimental estimation of physic-chemical characteristics of manganese raw materials such as softening temperatures and specific electric resistance of materials and charge mixtures on their basis. Rating system allows comparing metallurgical value of materials.

KEYWORDS: *Metallurgical value, experiment-calculated and calculation methods, extraction value, specific material and energy consumption, physic-chemical characteristics, rating, technogeneous raw materials.*

Quality downgrading of manganese ores worldwide, need for rational raw materials selection (domestic or imported) and changes in consumer requirements to the quality of manganese ferro-alloys lead to complicated analysis of manganese ore market including material and delivery costs, conditions of supply and, what becomes sufficient for ferro-alloy producers, metallurgical value of manganese raw materials.

Supply of world and national demand for high quality manganese ores and concentrates is realized mainly by traditional sources: Africa, Australia, Brazil and India [1] where ores usually do not require complex ore processing flowsheets.

In countries like Russia where deposits are represented by poor manganese ores with high phosphorus content but have comparatively low costs of extraction and ore-dressing [2, 3] ferro-alloy producers tackle the problem of production of high-quality low phosphorus ferro-alloy. Such countries with similar conditions have to decrease sufficient costs of production and possible way is a capability of determination of raw materials metallurgical value.

A promising manganese source for ferro-alloy industry is waste of different types: tailings, reject materials, slags, dusts and sludge from gas cleaning systems. Manganese content in these materials is often comparative with poor domestic manganese ores and the main obstacle for involvement of such materials into ferro-alloy production process is a need for their pretreatment to the melt (drying, sintering, etc.). Negative environmental effect of waste in the area of production facility is additional incentive for the use of technogeneous raw materials in charge mixtures. These non-standard materials also need for metallurgical estimation before involvement into technological process.

Price/quality optimum search for alternative raw materials should be made on the basis of the range of characteristics [4], including amount and composition of gangue, specific content of iron and phosphorus (comparatively to manganese), production technology of manganese ferro-alloy (high-carbon ferromanganese or ferromanganese silicon), specific consumption of materials and energy for selected technology. This all is so called metallurgical estimation of raw materials.

We propose two variants of method for metallurgical estimation of manganese raw materials: experiment-calculated and calculation [4, 5]. Peculiarity of proposed calculation method of metallurgical estimation is the use of thermodynamic simulation and technological calculation on it's basis which allows to determine basic engineering-and-economical performance indices with adequate accuracy without experimental-industrial or industrial melts. The choice of a variant of method depends on availability of representative sample of raw material (in chemical, mineralogical composition, etc.). Experiment-calculated method is used when a representative sample is available, otherwise, when only chemical composition is known, calculation method is used.

EXPERIMENT-CALCULATED METHOD OF METALLURGICAL ESTIMATION [4-6]

Method includes several stages:

1) Preliminary estimation of ore by specific content of phosphorus, iron (possibility of standard alloy production by manganese content) and also by amount and composition of gangue to determine a rational processing technology (production of high-carbon ferromanganese by flux/fluxless method or production of ferromanganese-silicon);

2) Determination of extraction value of basic elements on the basis of experiment or thermodynamic simulation of carbothermic reduction of manganese in multicomponent systems which correspond by their chemical composition to charge mixtures for ferro-alloy production technology;

3) Calculation of specific energy consumption on the basis of specific consumption of charge materials which is determined by technological calculations made with usy of results of thermodynamic simulation or experimental data on distribution of basic elements between metallic, oxide and gas phases;

4) Experimental study of softening temperatures and temperature interval of softening of raw materials which influence on the maximum temperature in submerged arc furnace;

5) Experimental investigation of specific electric resistance of ore samples and charge mixtures for production of ferro-alloy by pre-determined technology.

Preliminary metallurgical estimation of material is made by using formulas (1)-(5) for specific iron content, amount and composition of gangue which determine basic quality indices:

– KS (ore quality on phosphorus content)

$$KS = \frac{[P]/[Mn] - A}{[P]/[Mn]} \tag{1}$$

$$A = \frac{< P > 0{,}99}{< Mn > \eta_{Mn}} \tag{2}$$

where η – extraction value of element into alloy;
<P> и <Mn> – content of phosphorus and manganese in raw materials;
[P] и [Mn] - the same in alloy;
– RO (amount of basic oxides in conversion to dry material (manganese oxides in conversion to manganese):

$$RO = \frac{(< Mn > + < CaO > + 1{,}4 < MgO > - < SiO_2 >) \cdot 100}{100 - \text{m.l.i.}} \tag{3}$$

where m.l.i. – mass loss on ignition;
– MF (specific content of iron in material):
for ferro-manganese silicon (⩾73% Mn)

$$\text{MF} = \frac{< \text{Mn} >}{< \text{Fe} >} = \frac{[\text{Mn}]\eta_{\text{Fe}}}{[\text{Fe}]\eta_{\text{Mn}}} \geq 12 \tag{4}$$

for high-carbon ferromanganese (⩾78% Mn)

$$\text{MF} = \frac{< \text{Mn} >}{< \text{Fe} >} = \frac{[\text{Mn}]\eta_{\text{Fe}}}{[\text{Fe}]\eta_{\text{Mn}}} \geq 7{,}5 \tag{5}$$

The higher KS index, the higher technological value of raw material from the point of view of phosphorus content and more phosphorous raw materials can be added in charge mixture.

Coefficient RO shows the sum of basic oxides in raw materials; raw materials with RO<35 are preferred for production of ferromanganese silicon, those with RO>55 are preferred for flux-free smelting process of high-carbon ferromanganese, and raw materials with RO=35-55 are suitable for production silicomanganese and high-carbon ferromanganese using a flux method.

Criterion MF indicates specific iron content. For production of silicomanganese with manganese content ⩾ 73% this index should be >12, and for manufacture of ferromanganese with manganese content ⩾78% this index should be >7,5.

A preferable technology for raw material processing is proposed in a result of preliminary estimation on the basis of formulas (1) – (5). Then average chemical composition of charge mixture with selected material is calculated and used for subsequent thermodynamic simulation of carbothermic reduction process. Findings of thermodynamic simulation on distribution of elements between metal, oxide and gaseous phases are used in refined calculations of specific consumption of charge materials. Specific energy consumption depends on quantity of charge mixture needed for production of 1 t of alloy.

Obtained experimental data on softening temperatures and specific electric resistance are estimated in comparison with those of materials investigated earlier samples which were already used in ferro-alloy production process. As it is difficult to establish a precise analytical dependence of experimental data on physic-chemical characteristics of different materials with technical-and-economical performance of a furnace it is possible to take these characteristics as a basis of materials comparison.

Use of experimental data for metallurgical estimation is possible when representative samples of raw materials are available. It allows to perform an updated metallurgical estimation in comparison with calculated method. Even raw materials with similar chemical composition can differ greatly by gangue and phase composition, and these factors influence the technical-and-economic performance of ferro-alloy production process. Taking into account physic-chemical characteristics of raw materials makes metallurgical estimation more precise.

We propose to make a metallurgical estimation of manganese raw materials using a range of physic-chemical characteristics on the basis of their rating with maximum meaning of their

importance factor K_{imp}=1 for:

Reduction value of Mn (K_{Red})	1;
Specific energy consumption (K_{SEC})	1;
Softening temperatures (K_{ST})	0,6;
Specific electric resistance (K_{SER})	0,3;
Specific phosphorus content (K_{SPC})	1.

This approach involves comparison of new materials with studied earlier ones. Every characteristic makes a contribution into finite value which can be considered as a sum of characteristic values multiplied by their importance factors. The value of each characteristic is calculated relatively to best known or best studied before value. A summary index of raw material quality $K_{\Sigma} = K_{Red} + K_{SEC} + 0,6\ K_{ST} + 0,3\ K_{SER} + K_{SPC}$ is used in a follow-up rating estimation.

CALCULATION METHOD OF ESTIMATION

This method differs from experiment-calculated by not taking into rating estimation such characteristics as softening temperatures and specific electric resistance due to unavailability of representative samples. Calculated reduction extraction value of manganese into alloy, specific consumption of raw materials and energy in this case are usually used not only for rating estimation, but also as raw data for complicated economical calculations including delivery expenses, reloading expenses, etc.

It should be mentioned that countries which do not possess their own mineral resources of high-quality manganese ores (e.g. China, Japan, Russia) but having a domestic manganese ferro-alloys production facilities are more likely tend to consider waste manganese-containing materials as an alternative to manganese ores. As manganese-containing wastes can be of a comparable or even a higher quality than domestic ores it is necessary to pay more attention to their metallurgical estimation and use. Moreover, a cost of manganese unit in such non-standard materials can be sufficiently lower than in ores and concentrates. Involvement of manganese-containing wastes (dusts, slags, tailings, etc.) into technological process of ferro-alloys production is also accompanied by ecology improvement and decreasing of environmental pollution fines and penalties.

CONCLUSION

The proposed method of metallurgical estimation of manganese raw materials can be calculation or experiment-calculated. The choice depends on availability of representative samples of manganese raw materials. The experiment-calculated method provides more information about characteristics of raw materials. Calculation provides more capability for “on-the-fly” evaluation, search of rational variants and optimization.

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