Technology for the reduction of iron oxides in the processing of metal slag scrap in the oxygen converter

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Abstract. The characteristic features of slag formation and oxidative metal refining in 160-tonne converters of EVRAZ ZSMK JSC using metal slag scrap in the solid metal charge are considered. Technological advantages of the process are established for the reduction of iron oxides from the slag component of the iron-containing product in the processing of waste slags.

1. Introduction
Currently, in steelmaking the issues of meeting the needs for scrap metal are of particular importance in connection with the deterioration of the quality properties of collected scrap metal and a decrease in the amount of recycled scrap due to the improvement of continuous casting technology [1, 2]. Under the current conditions, it is necessary to improve the traditional composition and technological mode for the formation of solid metal charge using, in particular, iron-containing products for processing dump converter slags, including metal slag scrap. The latter is a conglomerate of metal and slag components, which remains in the slag pots after the liquid converter slag draining into the pit of the slag compartment.

2. Technology
In BOF-1 of EVRAZ ZSMK JSC, the slag cakes are removed from the slag pots and loaded with scrap metal into the converter in the amount of 10-50% from the weight of the solid metal charge with the corresponding adjustment of the heat part of the process. The weight of the material charge (cast iron and scrap metal) is 153 – 155 tonnes, including 24 - 27% of the solid metal charge. The chemical composition of cast iron varies in the range: 0.35 – 0.65% Si; 0.35 – 0.65% Mn; 0.08 – 0.12% P and 0.020 – 0.028% S. The temperature of cast iron is 1290 – 1320 °C.

Before casting, as a rule, preheating of scrap metal takes place in the converter. Coal from the Kuznetsk basin of the TOM brand is used as the main heat carrier. Oxygen for coal combustion is supplied with a flow rate of 150 – 250 m³/min. Duration of heating is at least 6 minutes.

The metal blowing with oxygen in the converters is performed through a 5-nozzle lance with Laval nozzles of a critical diameter 0.035 m and an angle of their inclination to the vertical axis of 15°. The operation is started at the tuyere position relative to the dead metal level 2.0 – 2.6 m with slag formation for 3 to 4 minutes, then the tuyere is lowered to 1.0 - 1.5 m. The blowing time is 20 – 21 minutes at an oxygen flow rate 350 – 450 m³/min. The total consumption of lime for melting is 6 – 8 tonnes, high-magnesia flux FOMI 0.9 – 1.1 tonnes, coal 2.7 – 3.1 tonnes.

It should be noted that a characteristic feature of the operation of converters at EVRAZ ZSMK JSC is the blowing of cast iron with a low manganese content, which creates certain difficulties in
organization of the slag melting mode and oxidative refining of metal. The use of high-magnesia fluxes for steel smelting and increase in the lining stability of oxygen converters determines an increase in the viscosity of converter slags and a decrease in their refining ability [3]. An increase in the temperature of the bath during the preheating of scrap metal and slag-forming materials improves the kinetic parameters of the process. However, slag formation often proceeds at an insufficient speed and is characterized by incomplete absorption of lime by slag and prolongation of the processes for harmful impurities removal.

It is known that the composition of slag and its physical properties change during converter smelting according to almost the same scheme [4, 5]. Slag in the converter is formed from oxides generated during oxidation of oxides impurities and slag-forming materials introduced into the bath: lime and high-magnesia flux. Primary slags, which are formed as a product of iron and iron impurities oxidation (primarily silicon and manganese), are characterized by a high assimilative capability with respect to calcium and magnesium oxides. Depending on the temperature conditions of the process and the properties of the slag-forming materials, the dissolution of lime and high-magnesian flux proceeds with a greater or lesser rate: the basicity of the slag and, simultaneously, the content of magnesium oxide in it increase.

3. Results and discussion

In the slag of the metal slag scrap the part of CaO is in a state bound to SiO2 and P2O5, while the other part is in the free state or in the composition of ferrites and calcium aluminoferrites is involved in the slag formation. So with the characteristic composition of the slag component: 35 – 40% CaO; 13 – 15% SiO2; 1 – 1.5% P2O5, 24.31 – 28.05% of calcium oxide in the composition of silicates will be bound; in the composition of phosphates – from 0.79 to 1.19%. Thus, technological value is 5.69 – 14.83% CaO.

Moreover, the eutectic of the slag component of the loaded slag metal scrap is enriched with CaO-containing mineral components, which is due to the relatively low melting temperature of the latter [3]. As a result, their rapid transition to the liquid state and participation in the process of slag formation from the first minutes of the operation can be assumed. In accordance with the calculated data, when the consumption of the loaded slag scrap is 10-50% from weight of the solid metal charge in the initial period of metal blowing, it is possible to increase the content of technologically valuable calcium oxide in the slag by 4 – 9%.

The slag component of the loaded slag metal scrap also contains about 10% MgO, mainly in the form of magnesiustite and magnesioferrite, and provides an increase in the content of magnesium oxide in the converter slag at the beginning of the blowing. In this case, at the end of the blowing its excessive supersaturation with MgO is prevented. The aforementioned contributes to a decrease in the viscosity of the primary slag and increases the degree of homogenization of the final slag, which generally increases the kinetic possibilities of metal refining from harmful impurities.

Thus, the dissolution of the slag component of the metal slag scrap allows acceleration of slag formation at the beginning of the operation, and the total amount of slag increases. At the maximum consumption of metal slag scrap – 50% from the mass of solid metal charge, the calculated increase in the amount of slag is 40 – 45%, which, of course, changes the hydrodynamic picture in the unit and requires the introduction of appropriate control actions to correct the smelting charge to prevent slag overrunning from the unit.

The analysis of the calculated data showed that for the conditions and characteristic temperatures under consideration, iron oxides can be reduced from the slag component of the loaded metal slag scrap. An industrially realized process has been developed for introduction of iron-containing products from waste slags processing using carbon-containing materials into the metal charge of oxygen converter and agitating the melt by the mixture of neutral gas and oxygen to recover iron oxides entering the bath [6].

In this case, the development of a solid-phase reduction is possible, when the reduction of iron oxides of the slag component occurs in the solid phase, followed by melting and reduction of iron
oxides from the melt, as well as a liquid-phase reduction, with the reduction of iron oxides of the slag component from the melt. In case of solid-phase reduction, the development of reactions in the direction of iron oxides reduction is possible only if the actual process temperature is higher than the temperature of the reaction onset, which is also provided by the technology under consideration. During liquid-phase reduction, the kinetic parameters of the process are favorably affected by the elevated temperature and intensive agitation of the melt.

At a relatively low bath temperature at the beginning of converter smelting, the oxidation of phosphorus is carried out by iron oxides, including those coming from the slag component of the dissolving metal slag scrap. This is due to the relatively low concentration of silicon in cast iron (0.4 – 0.5%) and, accordingly, silica in the primary slag, as well as to a slow increase in the bath temperature due to the greater cooling effect of metal slag scrap and the presence of calcium oxide binding $\text{P}_2\text{O}_5$ into complexes that firmly hold phosphorus in the slag and lower its activity.

The phosphorus content in the metal before its tapping using slag metal slag scrap is on average 0.017%. The basic slag basicity is 2.66 units, the iron oxide content is 24.45%, the metal temperature is 1629 °C, the phosphorus concentration in the cast iron is 0.08 – 0.12%. As for the phosphorus content in the metal before being tapped according to the traditional technology, its average value is at the same level. However, this ensures a higher distribution coefficient of phosphorus between the slag and the metal, which is apparently due to its increased entry into the bath.

In the normal converter smelting conditions, as a rule, the slag is formed with a high content of iron oxides, which is generally unfavorable for sulfur removal. The sulfur content in the metal before being tapped using metal slag scrap is on average 0.029%, and in the melting according to the traditional technology – 0.028%. It should be noted that in melts with metal slag scrap the slag oxidation is slightly higher, and its basicity and temperature conditions of the process are almost identical.

The analysis of the chemical composition of the metal at the tapping using metal slag scrap showed a marked decrease in the content of undesirable impurities of non-ferrous metals, in particular Cu, Ni, Cr, due to a change in the qualitative composition of the solid charge. The usage of the metal slag scrap and a corresponding reduction in the consumption of scrap metal, which is the main source of non-ferrous metal impurities in the converter bath with the traditional technological scheme for steel production, made it possible to reduce the concentration, in particular, of copper in the metal before its tapping from the unit by an average of 16%, and nickel – by 12.5%.

4. Conclusion
The proposed technology for the iron oxides reduction from the slag component of metal slag scrap allows the iron in the oxide form to be returned into production. Processing of metal slag scrap without efficient use of the slag component reduces the economic opportunities of the process.

References
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