The study on manganese behavior in oxidizing conditions of steelmaking processes

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Abstract. The possible limits of increase in the residual manganese content in the oxidizing conditions of steelmaking processes were studied by thermodynamic calculations. In the conditions of the current production the manganese behavior during carbon oxidation in the converter (300 tonnes) and electric steelmaking furnace (100 tonnes) was investigated. The industrial data confirmed the thermodynamic calculations. The developed technological methods in case of their implementation will allow the consumption of manganese ferroalloys to be reduced.

1. Introduction

With the increase in the production of steels and improvement of their quality, there is an increase in the consumption of ferroalloys. For Russia a serious problem is the supply of manganese ferroalloys, because its own production is extremely insufficient, and its increase is hampered by the lack of manganese ore reserves required for ferroalloy production.

A partial solution to the problem can be achieved by developing new resource-saving technologies that reduce the consumption of manganese ferroalloys.

This can be achieved by increasing the residual manganese at the end of oxidation processes and, especially, by using the technology of direct alloying with manganese oxide materials.

Such materials can include both manganese ore and concentrates, as well as technogenic wastes and secondary resources of the mining and metallurgical industry.

A special advantage of this direction is that for such technologies resources of small deposits of regional importance can be used. For Kuzbass metallurgical industry these may be manganese ores from the Durnovsky and Selezensky deposits, as well as ores from the neighboring Altai Territory.

In this regard, the issue of the manganese behavior in the oxidizing conditions of steelmaking processes is very relevant.

It should be emphasized that various options for optimizing the technologies of oxidation process and direct alloying have been tested in relation to the steel production conditions in both converters and open-hearth and electric steelmaking furnaces. However, in recent years, serious innovations have been introduced in the production technology. Therefore, the need for further study of this issue in relation to modern metallurgical processes is relevant.

2. Results and discussion

The thermodynamic analysis applied to Mn was carried out on the basis of tendency towards equilibrium of system C – Mn – O.
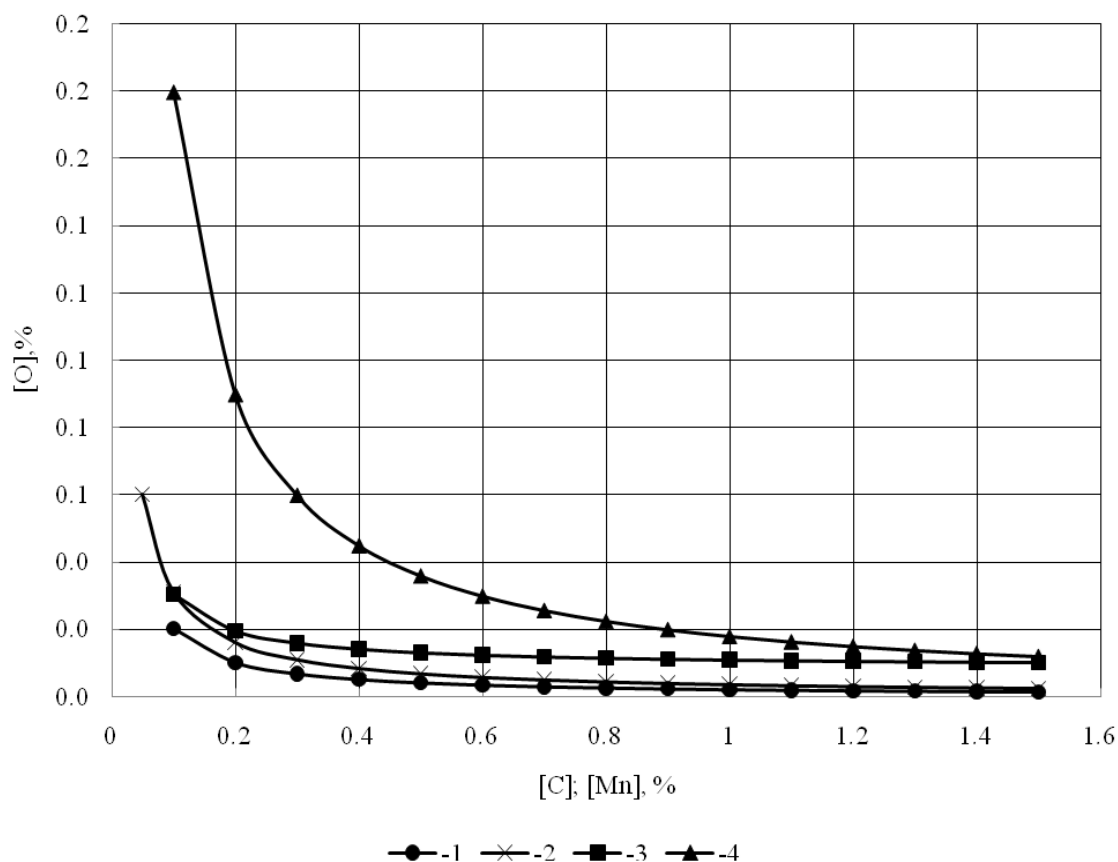
Usually when considering the manganese oxidation a reaction is used:

$$[Mn] + (FeO) = (MnO) + [Fe] \ (lgK = (6440/T) - 2.95) \qquad (1)$$
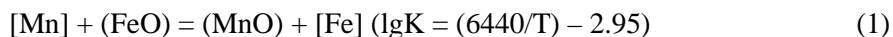
i.e. with the slag phase. However, in modern fast-flow steelmaking processes with a large consumption of gaseous oxygen the direct oxidation reactions can be used:

$$[Mn] + [O] = (MnO) \ и \ [C] + [O] = \{CO\} \qquad (2)$$
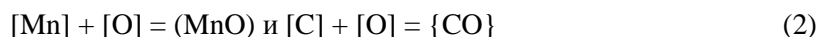
The obtained results are shown in figure 1.

Figure 1. The ratio of [C] – [O] – [Mn].
1- [C] с [O] by the reaction [C] + [O] = {CO} at Pco = 1 atm [2];
2 - [C] – [O] according to practical data for 300 tonne – converter;
3 - [C] – [O] according to practical data for arc steel smelting furnaces
[O] = - (0.00216/[C]) + 0.00884 [1];
4 - [Mn] – [O] by the reaction of [Mn] + [O] = (MnO) [2].

The analysis of the results shows that practically in the entire range of carbon and manganese concentrations, characteristic for oxidizing conditions of steelmaking processes, it is carbon that determines the oxygen content in the metal. Manganese in steel can not be oxidized at a concentration up to ~ 1.0%. Only when the carbon content is lower than 0.1%, the content of manganese should decrease.

The equilibrium content of carbon and manganese is shown in figure 2.
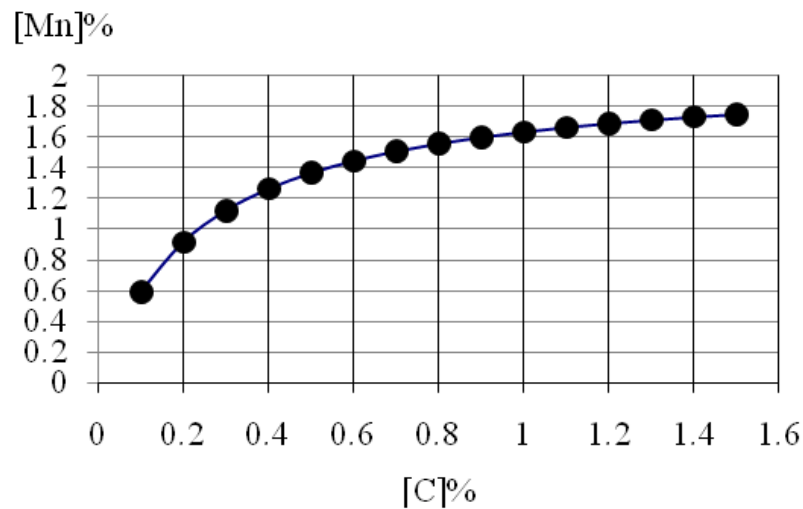
Figure 2. Equilibrium relationship [C] – [Mn] in the oxidizing conditions.

The joint behavior of carbon and manganese has been studied in the conditions of operating facilities – converter (converter with capacity 300 tonnes) and electric steelmaking (100 tonne arc furnace). The data on the manganese and carbon behavior in converter melting (300 tonnes) are shown in figure 3.
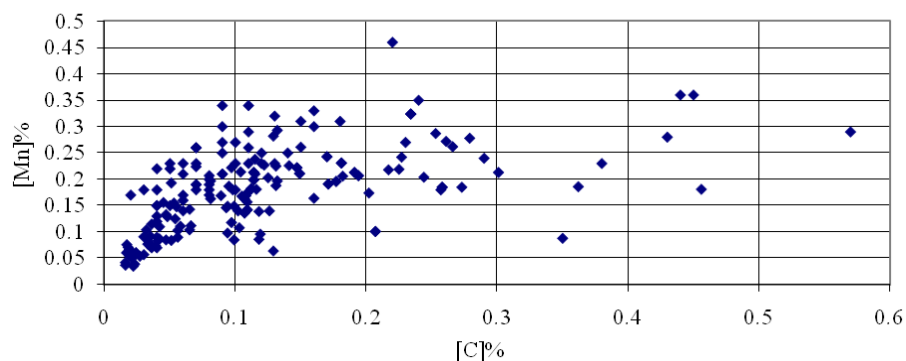
Figure 3. The ratio of [C] – [Mn] to the converter melting.

Data on the manganese and carbon behavior in the electric steelmaking furnace (100 tonnes) are given in figure 4.
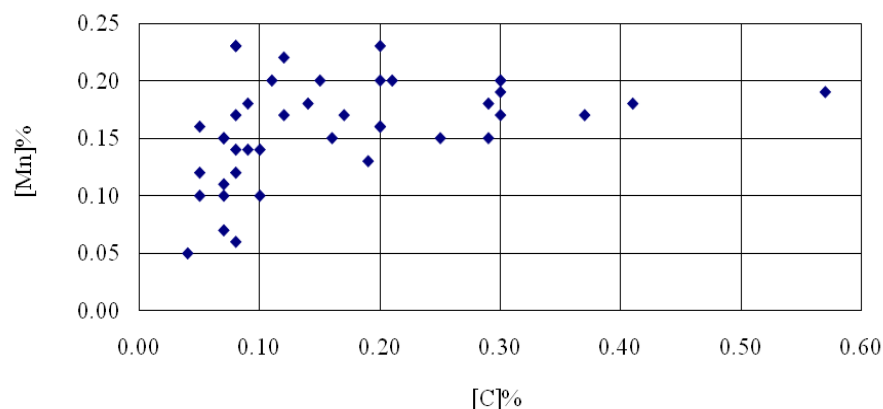
Figure 4. The ratio of [C] – [Mn] during melting in the electric arc furnace (100 tonne).

The analysis of the obtained industrial data shows that they correlate well with the presented above thermodynamic calculations.

It is clearly seen that the content of manganese practically does not change during the oxidation of carbon. Only after achieving a carbon content of 0.1%, a rapid manganese oxidation begins. The concentration of manganese with carbon of less than 0.1% becomes lower than the calculated values. It reaches 0.05%. This can be explained by the fact that at this carbon concentration the limiting stage of the oxidation process changes. The rate of the process begins to be limited by the rate of mass transfer of carbon in the metal. Excess oxygen begins to interact actively with other elements, such as manganese and iron.

3. Conclusion

The analysis showed that the main directions for optimization of the oxidation process technology in order to save manganese ferroalloys are:

- increase in the manganese content in the metal due to the use of a metal charge with the increased content of manganese;
- direct alloying with manganese from oxide manganese materials;
- control of carbon and, accordingly, stopping of the process at its maximum permissible concentrations at the final stages of metal blowing with oxygen.

References

[1]   Povolotsky D Ya, Roshchin V E and Malkov N V 1995 *Electrometallurgy of Steel and Ferroalloys* (Moscow: Metallurgy) p 592

[2]   Grigoryan V A, Belyanchikov L N, Stomakhin F Ya 1987 *Theoretical Foundations of Electric Steelmaking Processes* (Moscow: Metallurgy) p 271