



ANALYSIS OF SLAG FORMATION AND THEIR CHARACTERISTICS DURING MELTING OF FERROUS METAL ALLOYS

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The relevance of the issue of metal processing in conditions of limited commodity markets for industrialized countries has become increasingly acute in recent years.

The rapid growth of the machine-building complex and the attractiveness of the export of rolled metal against the backdrop of a limited raw material base for ore, the slow development of explored deposits and practically stopped geological exploration of new deposits create an ever-increasing shortage of metal raw materials for metallurgical and foundry enterprises.

On the other hand, the process of mass disposal of fixed assets (obsolete machines, metal structures, obsolete railway tracks, etc.) due to their high deterioration is gaining momentum.

Therefore, today there is a very high interest of metallurgical and foundry industries in searching for raw materials on secondary markets, and the ever-increasing cost of energy resources forces them to look for more efficient ways of processing them into marketable products.

Melting units in use today can be divided into two broad classes: flame metal processing units and electric melting units.

The class of electric melting units can be divided into the following large groups:

- resistance furnaces;
- arc melting furnaces (DC and AC);
- induction melting furnaces (industrial and medium frequency), channel and crucible.

Resistance furnaces are not used for melting ferrous metals due to low operating temperatures. For non-ferrous metals, they are used only as heat retainers and are practically not used as melting units due to low productivity.

Research conducted more than two decades ago remains a useful overview of the main causes of slag circulation limitation in a steel mill [1]. For both electric arc furnaces and basic oxygen furnaces, the main benefits of slag formation are increased purity of the steel oxides, lower consumption of reoxidizer, reduced phosphorus (or silicon) recovery and increased furnace refractoriness.

"Oxide purity" refers to the concentration of impurities in the liquid steel. The basis for the effect of slag on oxide purity is that the FeO and MnO in the slag are a source of oxygen and continue to react with aluminum (or other re-oxidants)



dissolved in the steel to form inclusions of aluminum oxide (or other oxides). This continues until the concentration of FeO and MnO approaches zero. This stable formation of new oxide inclusions leads to an increase in the total inclusion concentration in the steel: a relationship between inclusion concentration and slag composition (%FeO + %MnO) has been reported [3]. The lower inclusion concentration (%FeO + %MnO) was less than about 4%. At the same time, the influence of (FeO + MnO) on the composition of the oxides has subtleties: the reduction regime resulting from the retention of several percent of FeO and MnO in the slag served to delay the transition of molten magnesium into steel and, therefore, delayed the formation of magnesium inclusions (approximate composition MgAl₂O₄) [2]. Because magnesium oxide inclusions interfere with the microstructure of continuous casting, it may be beneficial to delay the formation of magnesium oxide inclusions (by retaining some FeO and MnO in the slag) during the alloying process to produce cast steel products.

Table 1
Iron slag chemical composition (wt%) and production level [2][3][4][5][6]

Types of slag		CaO	SiO ₂	Al ₂ O ₃	MgO	Mn O	FeO _x	Normal slag rate (t slag / t raw metal)
Blast furnace slag		34 – 43	27 – 38	7 – 12	7 – 15	0.15 – 0.76	0.2 – 1.6	0.3
Steel slag	AKP	45 – 60	9 – 22	1 – 7	5 – 17	2 – 14	10 – 35	0.126
	EYoP	35 – 60	9 – 20	2 – 9	5 – 15	1 – 8	5 – 30	0.169
	KQIP	30 – 60	2 – 35	5 – 35	1 – 10	0 – 5	0.1 – 1.5	0.030
FeCr slag		2	30	26	23	–	5	1.2

The reduction of phosphorus by reoxidation has a strong effect on increasing the slag content, and this is easily seen from a simple mass balance. Calculations are based on steel that contained 800 ppm dissolved oxygen when pressed, 0.25% P in the slag when liquefying the steel, and a total of 25% FeO and MnO. It was assumed that during the casting process the liquid metal was overoxidized by aluminum, and after overoxidation, an Al content of 0.05% was found in the steel ingot. It has been determined that the required amount of reoxidizer (Al) is the addition of dissolved Al (0.05% or 0.5 kg Al per ton of steel).

Also notable is the estimated rate of phosphorus recovery; Phosphorus reversal occurred as a result of all the phosphorus in the raised slag (0.25% by weight of the slag) returning to the steel during reduction (reoxidation). According to the data, without a slag trap, the amount of slag from oxygen converters was 10-



15 kg per ton of steel, which led to phosphorus conversion of about 30 ppm; when using a refractory plug, slag lift was reduced to 3-5 kg/t and phosphorus recovery was reduced to approximately 10 ppm.

As described by foreign scientists Abraham and Chen [4], at the manufacturing plant, a special size metal was introduced into the slag in the liquid metal layer, and the thickness of the slag on the surface of the liquid metal could be measured by easily measuring the height of the slag adhering to it.

The adverse effects of slag resulting from wear of furnace lining refractories are usually attributed to the presence of MnO in the steelmaking slag. Experimental studies have shown that increasing the concentration of manganese oxide increases the corrosion rate of MgO-carbon linings commonly used for slag lines [5]. The corrosive effect of MnO is explained by the oxidation of carbon by MnO (leading to the loss of refractory carbon) and the rapid mass transfer of MnO in the slag [6].

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