Study on Arcing Phenomenon in Electroslag Remelting Process

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Abstract
Arcing often happens in the electroslag remelting(ESR) process and will lead arc point on the ingot surface which affect the quality seriously of ESR ingot. In this paper, the causes of arc point were analyzed for 200kg iron-chromium alloy ESR ingot and influence factors of causing arc point were studied by industrial experiment. The results show that the measures that control of low voltage and high current of the power system and using the Al_2O_3×24%＋CaO×3%＋CaF_2×70%＋MgO×3% slag can prevent the generation of arc spot for the for 200kg iron-chromium alloy ESR ingot effetely and to improve the stability of the smelting process greatly.
Key Words: ESR, ARC SPOT, POWER SYSTEM, REFINING SLAG

1. Introduction

The process, that the power pole was melted by the high temperatures which generated from the slag resistance region by the large current through, is called ESR process [1]. The main loop of the smelting process is composed of the electrode, slag pool, metal bath, steel ingot, tank bottom and short net and transformers [2]. The main circuit current is not smooth when the process parameters are instability sometime, which leads to divert traffic between the ingot and mold. If the divert traffic is too high in one place, the slag jacket will rupture, and arc discharge is generated due to the conduction between the ingot and mold, resulting the holes formed in the ingot surface [3]. At present, there were few reports on arcing phenomena in remelting process. In this paper, effect of power systems, the composition of slag and thickness of the slag layer on arcing was studied in electroslag remelting process.

2. Industrial Experiments

The electrodes used in this experiment are cast from smelting furnace, the diameter is 140mm, and the capacity of electroslag remelting furnace is 200kg. The main parameters of electroslag process were shown as Table I.

The arc points appearing in smelting process are shown as Figure 1. As can be seen from Figure 1, the ESR ingot body is impacted to produce some small holes. It brought to the defects for surface quality and internal organization of the ESR ingot, and is not conducive to the subsequent forging rolling process.

Table 1. Parameters in ESR smelting process

Ingot shape/kg	Smelting time/min	Amount of slag/kg	Thickness of lower slag layer /mm	Upper slag layer thickness/mm	Slag composition
200	82	12	95	110	24%Al_2O_3+5%CaO +71%CaF_2
Electrode diameter/mm	Voltage/V	Electric current/A	Water Pressure/MPa	Slow cooling method	Inlet pipe size/mm

140	55	5500	4	Sand burial	60

Figure 1. The arc points in the ingot surface

The ingot is cut along the position where the arc point appeared, and the sectional is pickled corrosion. It can be seen from Figure 2, the arc point has a certain depth, and dendrites along the direction of the arc point become equiaxed and extend to the core part. It can be inferred, arc phenomenon is generated that current breakdown from the ingot external to the internal. Dendrites are re-melted and then solidified by discharge phenomenon of the department, after the formation of it, and then the equiaxed is formatted because of the smaller thermal field gradient surrounding. The grain is large and loose, and undermines the continuity of the columnar grain. The arcs point is deep, and affects the finished product rate.

The instability of the process parameters, the series of problems caused by such as current, the furnace mouth voltage electrode buried depth and the gradual increase thickness of the slag layer, are likely to lead to arcing[4].

Figure 2. The arc points in the sectional of ingots

3. Results and Discussion

3.1 Power System

The power parameters are explored by regulating the voltage and current in smelting process. Current is less stable in the process that the process current increased from 5000A to 5500A, when voltage to 50V. The current is stability in the range 5200A-5300A in the process, when voltage to 45V. Metal pool depth and the depth of electrode buried is ideal match. This is because that, when the voltage is too high, the electrode buried depth will be too shallow, electro-slag process will become unstable, electrode will float in the slag surface, current will fluctuate, and the slag surface temperature will be too high. This will result that, gas and inclusion in ingot increased, burning of alloying elements increases, especially easily oxidized elements. Simultaneously it result the surface of the ingot is in a poor shape. Therefore, the ideal process parameters are determined as follow: voltage 45V, current 5250A (± 50 A).

3.2 Slag Composition

In order to study the effect of slag on arc points in the smelting process, the changing of the ratio of slag system were tested. The experimental schemes of different slag are shown in Table 2.

Table 2. Experimental schemes of different slag

	Al_2O_3/%	CaO/%	CaF_2/%	MgO/%
Scheme 1	24	5	71	
Scheme 2	20	5	75	
Scheme 3	15	3	82	
Scheme 4	15	8	77	
Scheme 5	24	5	69	2
Scheme 6	24	3	70	3

The trial involved four kinds of components and the effect of slag component on thermo-physical properties of system is shown in Table 3:

Table 3. Thermo-physical properties of different slag components

Slag Component	Melting point /℃	Impact on the viscosity	Impact on conductivity
CaF_2	1270-1350℃	Reduced Significantly	Improve
CaO	2580℃	Reduced	Reduced
Al_2O_3	2050℃	Improve	Reduced Significantly
MgO	2852℃	Improve	Reduced

It is concluded through different slag experiments: 1) the establishment of the remelting process stabilizes gradually, when Al_2O_3 is from 24% to 15%. However, it leads to lower melting temperature of the slag, due to reducing significantly of the resistivity of the slag. And then the heat of the slag is not enough, quality problems is prone to generated, and the point of the arc is generated most likely in the surface of the ingot. 2) When a certain amount of MgO is added, slag smelting stability has improved to some extent, plastic and peeling slag clothing has been some improvement. 3) Since MgO and CaO increases the viscosity of the slag, a certain amount of the CaO content should be reduced while the amount of MgO added, in order to ensure that the slag having a certain degree of mobility. 4) Slag system is relatively stable in the smelting process of Scheme 6, and the ingot surface quality is better.

3.3 Thickness of the slag layer

It has taper along the axial of 200kg ingot mold, the cavity cross-section changes in time, which lead to the change of slag pool depth in melting process. Catchy is 210 mm and bottom is 240 mm, resulting the depth of catchy slag pool is 30% more than the bottom. The refining effect is different due to changes in the upper and lower slag pool depth. The appropriate amount of slag should be selected, so as to ensure the gap of smelting environment is smaller before and after. It is 5% -10% of the consumption residue accounts of slag clothing in the ingot surface (The slag clothing thickness is calculated as 0.5mm-1mm). Variations

thickness of the slag layer in bottom and top with the amount of slag is shown as Table IV.

When the amount of slag is 12kg and 16kg, current has some fluctuated in smelting, and it is large in smelting late. When the amount of slag is 10kg, current is very stable in pre-stage, and it has a certain degree of volatility in late stage. When the amount of slag is 8kg, current is stable in pre-stage and mid-stage, and it has a slightly fluctuations in the latter.

Table 4. Thickness of slag layer changes with different amount of slag

Amount of slag	the slag layer thickness of bottom	the slag layer thickness of top
8kg	60-65 mm	80mm
10kg	75-80 mm	95mm
12kg	90-95 mm	110mm
16kg	120 mm	140mm

When the amount of slag is 12kg and 16kg, there is more arcs point in the ingot surface. It still has a small amount of arc spot when the amount is 10kg. There is no arc spot when the amount is 8kg, and its surface quality is better. As can be seen from the above phenomenon, the thickness of slag layer is thicker, the molten metal bath is shallower, and the depth of the electrode buried reduces passive, lead to instability of the electrical parameters, thereby affecting the quality of ingot smelting. The correctness and rationality of the simulation, that the slag pool depth on the current density and temperature field is verified directly from the relationship between the stability of the current and the amount of slag.

Sum up, it is can be guaranteed a good stability of the electrical parameters, and also having good slag jacket peel ability, uniformity thickness of slag coat and better surface quality of ingot, what the amount of slag is 8kg.

3.4 Optimization Process

Based on the above results, the optimization smelting has been carried out, which the voltage is adjusted to 45V, current is controlled for 5250A (± 50 A), and 8kg slag Al_2O_3 × 24% + CaO × 3% + CaF_2 × 70% + MgO × 3% is used in the smelting process .The structure and surface of ingot after optimization is shown in Figure 3.

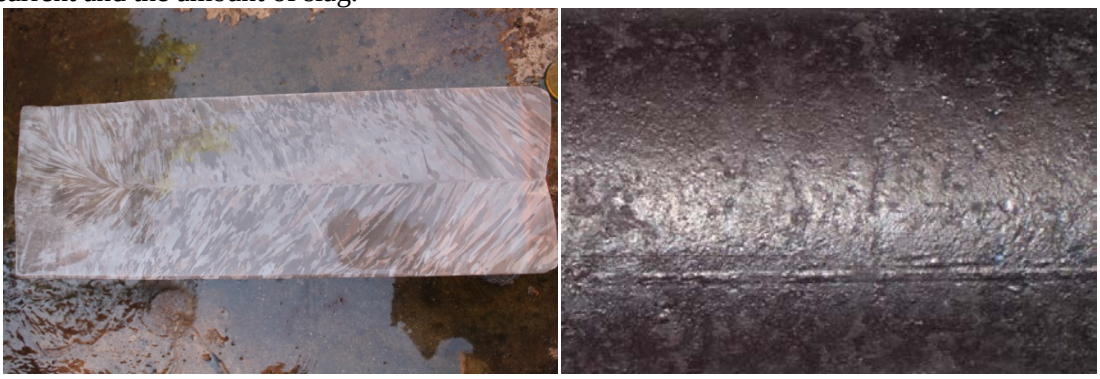

Figure 3. The structure and surface of ingot after optimization smelting

As can be seen from Figure 7, columnar crystals distribute evenly and consistency, the surface is dense and smooth, quality is good, and there is not arc point of the ingot, after the process is optimized. Therefore, the optimization process can effectively verify and solve the problem of the arc point in ingot surface.

Conclusions

The low voltage and high current of the power system is advantageous to the stability of electroslag remelting smelting process. The ideal parameters of power system are voltage 45V and current 5250A (± 50 A) for 200kg ingot.

Using

Al_2O_3×24%＋CaO×3%＋CaF_2×70%＋MgO×3%

slag can improve the stability of the smelting process and the smelting effect greatly.

The deep slag pool is prone to make arc phenomenon and can thin slag avoid generating arc effectively.It is can be guaranteed a good stability of the electrical parameters and also having good slag jacket peel ability, uniformity thickness of slag coat and better surface quality of ingot, what the amount of slag is 8kg for the 200kg ESR.

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