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RESEARCH ON SMELTING LOW-CARBON FERROCHROME IN A PLASMA FURNACE

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ABSTRACT By a non-transformed arc plasma torch whose gas is nitrogen, scrap of high-carbon ferrochrome was heated and melted in a sealed furnace. When the liquid bath was at 1 600 ℃, top blowing of oxygen began to decrease the bath's carbon without stopping plasma operation for its temperature addition and maintennace of at least 1 750 ℃. The liquid bath was agitated by bottom-blowning nitrogen. In the experiments low carbon Fe-Cr have been obtained whose composition respectively was 0.45% carbon, 50.75% chrome and 0.42% carbon, 70.25% chrome. Loss of chrome could be less than 5%.

KEY WORDS plasma furnace, ferrchrome, smelting

At present, the decarbonisation process by top or bottom the oxygen furnace is widely used for the making of medium and low-carbon Fe-Cr at home and abroad. These methods have many advantages: easily operating, high efficiency, good technical and economical targets. However, at the normal atmosphere, it is difficult to take low carbon Fe-Cr containing less 1% C, because the temperature of bath must be more than 1 900 ℃. In order to decrease the oxidization of chrome and to rise the lining durability, producing medium carbon Fe-Cr that contained carbon 2% by means of the oxygen furnace is best [1].

Plasma melting which has been developed in recent twenty years has been used for producing of high-carbon ferro-alloys and their advantages have been shown [2]. Not only is plasma a heat source that has high efficiency of the electric changes to heat, also the arc atmosphere can be controlled. If it is used for heat liquid high-carbon Fe-Cr under inert atmosphere for proceeding low or micro-carbon Fe-Cr by means of decarbonization process. The working processes will be simplify greatly and the efficiency will be raised. In the experiment low ferrochrome has been obtained whose containing carbon was less than 0.5% and the loss of chrome was less than 5%.

1 EXPERIMENTAL

The test process is shown in Fig. 1.

Test equipments are (1) plasma torch (provided by Tsinghua University, power-100 kW; type- non-transformed arc metallic plasma torch with water cooling; working gas - nitrogen.). (2) smelting furnace (capacity-100 kg; lining - by taping magnesite mixed with brine; The venting brick mounted at the bottom), as shown in Figs. 2 and 3. (3) Temperatures measurement – a W – Re thermocouple protected by MgO – MoO ceramic tube mounted at the bottom of furnace, which was connected with a millivoltmotor.

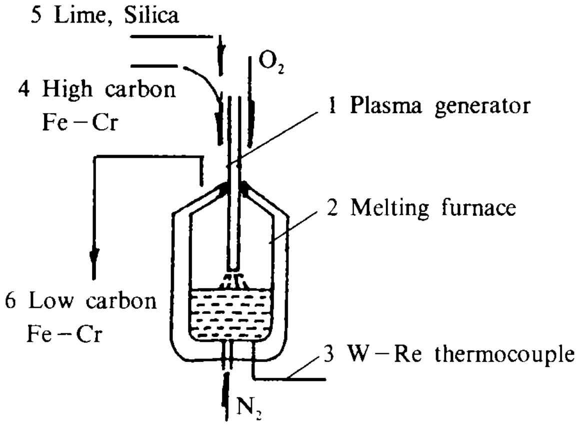

Fig. 1 Schematic chart of the test process

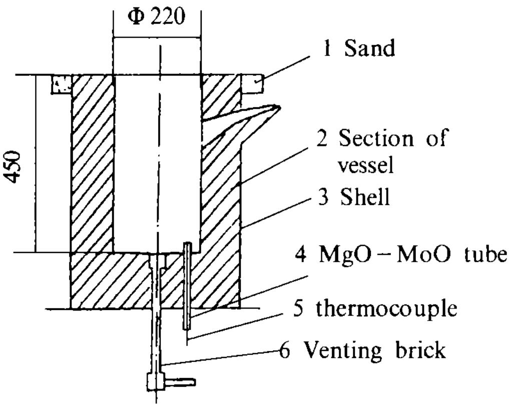

Fig. 2 Section of vessel

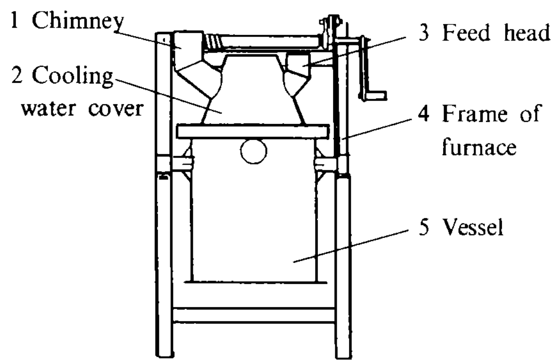

Fig. 3 Schematic chart of the test device

Table 1 Composition of high – carbon Fe – Cr

Group No.	Element content /%				
	C	Cr	Si	P	S
1	8.39	66.34	0.37	0.023	0.050
2	4.10	51.52	–	–	–

Table 1 shows the composition of high – carbon Fe – Cr.

Forming slag materials are Lime (CaO 91.0%; SiO_2 2.5%) and Silica (SiO_2 98%) Gases are commercially pure bottle nitrogen and oxygen.

2 REACTIVE PRINCIPLE

When blowing oxygen into the liquid bath of the high – carbon Fe – Cr, flowing chemical actions take place:

$$[Fe] + 1/2O_2 = FeO \qquad \Delta G_1^\circ = -232\,714 + 45.31T \ \ J/mol \qquad (1)$$

$$2[Cr] + 3/2O_2 = Cr_2O_3 \qquad \Delta G_2^\circ = -1\,131\,981 + 256.69T \ \ J/mol \qquad (2)$$

Decarbonization will take place after the bath's temperature was risen immediately:

$$Cr_2O_3 + 3[C] = 2[Cr] + 3CO(g) \qquad \Delta G_3^\circ = 755\,840 - 478.86T \quad J/mol \tag{3}$$

$$\lg K = \alpha_{[Cr]}^2 (P_{CO}/P^\circ)^3 / \alpha_{[C]}^3 \alpha_{Cr_2O_3} \tag{4}$$

In the molten metal the Cr_2O_3 is an independent phase, so $\alpha_{Cr_2O_3} = 1$. Under the atomosphere blowing the $P_{CO} = P^\circ (= 10^5 Pa)$, there is an empirical equation:

$$\lg([Cr\%]/[C\%]) = 15\,000/T + 9.33 \tag{5}$$

If the [Cr]/[C] keeps constant, the lower the CO partial pressure, the more advantages the decarbonization and oxidized chrome will be decreased.

3 SMELTING PROCESS

The oxygen is injected into the bath through auxiliary-gas system of the plasma gun. The supplying gas parameters is shown in table 2.

Table 2 The supply gas parameters of the plsama gun

Supplying gas	Working pressure p/MPa	Flow of gas meter-flow $v_1/m^3 \cdot h^{-1}$	Flow of gas standard flow $v_2/m^3 \cdot h^{-1}$	O_2:N_2
main-gas (N_2)	0.35	4.5	9.36	1 : 1.4
auxiliary-gas(O_2)	0.35	3.0	6.70	1 : 1.4

The bath's carbon should be less than 0.5% and chrome more than 60% at the end of blowing. At blowing oxygen period the furnace atmosphere is $O_2:N_2 = 1:1.4$. Because the supplying oxygen ability is limited (for example, lower oxygen pressure; non supersonic flow etc.), so the oxygen utilization factor is lower about 70%. Therefore, at the carbon drop period the composition furnace atmosphere is $O_2 : N_2 : CO = 0.3 : 1.4 : 1.4$. That the CO partial pressure is $P_{CO} = 1.4/3.1 = 0.45 \times 10^5$ Pa. The temperature of the blowing end can be calculated by the equation (5). It must be more than 1 974 K (1 701 ℃). In the just after decarbonization, the bath's carbon content is higher and the [Cr]/[C] is lower, so the temperature at the beginning of blowing oxygen may be reduced properly. It is provided for ≥1 650 ℃ in the test.

The scrap of high-carbon Fe-Cr is fed in furnace and melted by the plasma torch. After the charge is melting-down, the slag-making materials which make up about 3 percent of the total scrap is added successively (lime and silicon). The basic capacity of slag should get $CaO/SiO_2 = 1.0$. When the bath's temperature risen to 1 600 ℃ , the auxiliary-gas of the plasma gun changes nitrogen for oxygen. That blowing oxygen begins to decrease the bath's carbon and the liquid bath is agitated by bottom-blowing nitrogen. The carbon is oxidized quickly and the temperature is risen speedily when the bath's carbon is higher at earlier stage, therefore the power may be reduced or dumped for the bath's temperature maintenance of at about 1 750 ℃ . According to the time of supplying oxygen that was calculated, the end of blowing is determined. After tapping a sample was taken for analyzing.

4 RESULTS AND DISCUSSIONS

Table 3 shows the composition in the end and the recovery ratio of chrome.

Table 3 The composition in the end and the recovery ratio of chrome

Heat No	Composition of materials/%		Composition of low carbon Fe−Cr/%		Recovery of Cr/%*	Temperature. at the end t / ℃
	C	Cr	C	Cr		
1	4.10	51.25	0.45	50.75	95.65	1 735
2	8.39	66.34	0.42	70.25	97.46	1 742

* The amounts of carbon oxidized had been deduced in the calculation.

The low−carbon Fe−Cr is produced by the method of the blowing oxygen decarbonisation. It is not rely on the heat of reaction that the elements is oxidized and the metal bath is in the inert atmosphere. So that in the rising stage of temperature the elements oxidation are reduced, and the carbon is oxidized easily in the carbon oxidation stage, the chrome is prevented to oxidation. As a result the oxidation loss of chrome is less than 5%.

Because the carbon monoxide was diluted by a large amount of nitrogen, the CO partial pressure was reduced. So that the critical temperature gone down which the carbon was oxidized in preference to chrome. So that in the experiments low carbon Fe−Cr (C ≤0.5%) was obtained at the temperature ≤ 1 750 ℃

According the data in the Table 3, the CO partial pressure can be calculated respectively and its values were 0.65×10^5 Pa and 0.74×10^5 Pa. If the condition of the furnace sealed is improved the CO partial pressure may be less than 0.5×10^5 Pa.

5 CONCLUSIONS

(1) It is feasible that the liquid high−carbon Fe−Cr reaches a high temperature heated by the plasma gun and oxygen is started to inject in order to reduce carbon and turn out low−carbon Fe−Cr finally. The oxidation loss of chrome can be keep less than 5%.

(2) In the industry the liquid high carbon Fe−Cr was produced in the electric shaft furnace and then feed it into the ladle furnace with a sealing cover, after that it is heated by the plasma gun and blowing oxygen to carbon drop so as to produce low or micro−carbon Fe−Cr. This method will simplify the process and decrease the cost of production.

(3) Because the carbon content of high carbon Fe−Cr is about 4% ~8%, so that the decarbonization requires a large amount of oxygen. Therefore in the industry the supplying of oxygen only by plasma gun will not meet the requirement. It is necessary to improve the supplying oxygen method.

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斜轴泵配流副的理论与试验研究

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摘要　动态测试了斜轴泵配流副的油膜间隙．在综合考虑配流副泄漏量、功率损失和抗污染磨损能力的基础上，对描述配流副工作状态的参数进行了优化．根据理论分析和试验研究，对配流盘的结构进行了改进，增强了配流副的抗污染磨损能力，从而延长了泵的使用寿命，提高了泵的工作可靠性．

关键词　斜轴泵，配流副，优化，动态测试

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等离子炉熔炼低碳铬铁

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摘要　采用以氮气为工作气体的非转移等离子枪，在密闭熔炼炉内熔化块状高碳铬铁，加热至 1 600 ℃ 后开始由顶部向熔池供氧降碳，同时继续加热使熔池温度维持在高于 1 750 ℃，熔池底部通氮气搅拌。试验获得了含碳、铬分别为 0。45%，20。25% 和 0。42%，70。25% 的低碳铬铁，铬的氧化损失保持在 5% 以下。

关键词　等离子炉，铬铁，熔炼