NEW METHOD TO PRODUCE FeNi NUGGETS FROM LOW GRADE ORE BY SEMI-MOLTEN REDUCTION

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ABSTRACT

With the decrease of deposit of high grade ore, more low grade ore will be used in the ferroalloy production, resulting in the high energy consumption in the traditional EAF process. Semi-molten reduction process at the lower operation temperature, taking the ferronickel alloy production with the low grade nickel laterite as an example, was suggested in present study.

The effect of temperature, carbon dosage and the flux addition on the recovery ratio of the elements were studied with the theoretical calculation and the experimental. It showed that the increase of temperature and the addition of flux promote the formation of the alloy nugget. The increase of the carbon dosage is beneficial for the reduction of iron and bad for the nickel content of the alloy. According to the experimental, the prefererable process for the ferronickel nuggets might be as follows: the temperature 1400°C, the carbon dosage with the C/O ratio of 0.67 and the quaternary basicity 0.60. Under these conditions the nickel content in the metallised product reached 12.6% and the recovery ratio 96%.

1. INTRODUCTION

As a commercially valuable metal, nickel is largely used in production of stainless steel or high temperature alloys [1, 2].

In the last decade, the rapid increase of demand for stainless steel has led to a significant rise in ferronickel production. In 2011, about 60% of the nickel was extracted from sulfide, even though laterite accounts for 70% of world nickel resources [2, 3]. However, with the continuous depletion of economical sulfide ores, much more attention has been drawn to laterite processing.

Nowadays, the rotary kiln-electric furnace (RKEF) process is largely used in ferronickel works in China due to its good adaptability for various nickel content laterite [4-6].

However, the high amount of water and gangue in laterite usually requires higher energy consumption especially for the lower grade laterite ores. Hence, developing a novel process with low energy consumption becomes a hot topic in the production of ferronickel with laterite.

A few researchers tried to use the direct reduction and magnetic separation process to get higher grade ferronickel concentrate before being charged into electric furnace, nevertheless, it is still difficult to enhance the agglomeration of metal because of insufficient temperature and the total energy consumption is still very high because of the long time heating and another smelting process with EAF [7, 8].

The rotary hearth furnace (RHF) has been successfully applied to produce iron nugget directly from iron ore with coal which is regarded as the new iron-making technology (ITMK3).

Therefore, a new process was proposed to prepare ferronickel directly by rotary hearth furnace in this study.

2. THEORETICAL CALCULATION

A thermodynamic study was conducted by using FactSage software due to its reliable and abundant database for minerals. The chemical composition of raw laterite ore was shown in table 1. In this study, it was assumed that all the nickel existed as NiO, the iron presented as Fe_2O_3; and the calculation of carbon dosage was based on the total oxygen content in the form of NiO and Fe_2O_3, the resultant gas was CO.

Table 1: Chemical composition of nickel laterite, mass%

Ni	TFe	FeO	SiO_2	MgO	CaO	Al_2O_3	Cr_2O_3	P	S	Water*
1.81	17.87	0.44	34.97	13.50	1.54	4.75	0.51	0.005	0.064	17.35

*Water=free water+crystal water+ hydroxy group

2.1 Effect of Carbon dosage

Figure 1 showed the thermodynamic calculation results of iso-reduction-degree of Fe and Ni at different temperature and carbon dosage. Obviously, in order to improve the content of Ni in ferronickel alloy, NiO should be totally reduced, while Fe_2O_3 was better to be reduced incompletely.

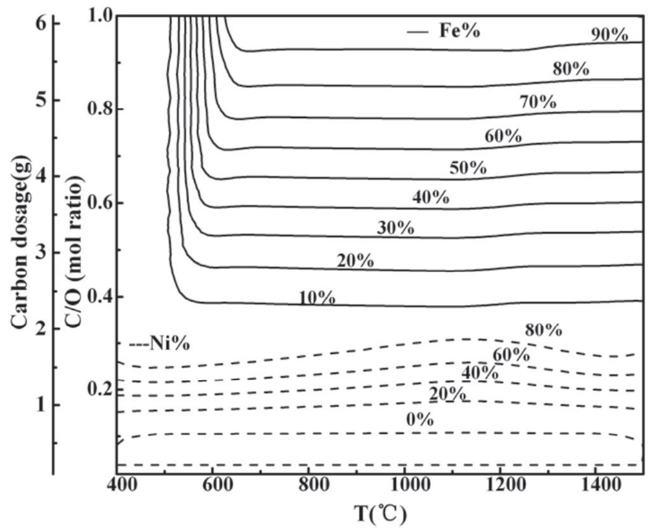

Figure 1: ISO-reduction degree of Fe and Ni with increase of temperature and carbon, mass of carbon dosage was based on 100g laterite

2.2 Effect of CaO addition

As for nickel laterite, which consists largely of the magnesium silicate, the influence of CaO on generation of liquid phase was calculated thermodynamically with the software Factsage. CaO was added to modify the quaternary basicity—$(CaO+MgO)/(Al_2O_3+SiO_2)$ from 0.40 to 0.60 by every 0.05, and the corresponding viscosities of molten slag between 1400~1600℃ were also calculated. The results are shown in figure 2, in which CaO could definitely enhance the formation of low melting temperature components and generate more liquid phase, particularly before 1300℃.

The increase of basicity can significantly reduce the viscosity of molten slag above 1400°C, which is beneficial for the separation between slag and metal.

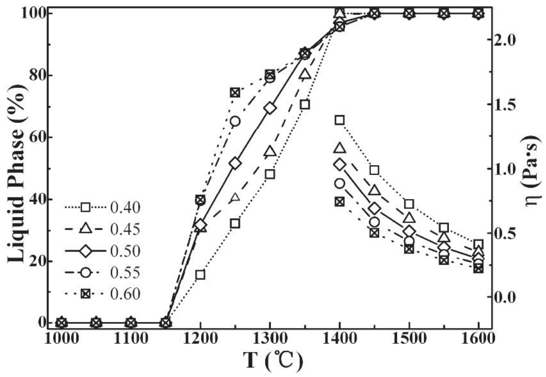

Figure 2: Influence of Temperature and CaO addition on liquid phase amount and viscosity

3. EXPERIMENTAL

3.1 Experimental scheme

In order to investigate the effect of temperature and CaO addition (basicity) on ferronickel nugget preparation process, a series of reduction experiments (table 2, 3) were carried out in a $MoSi_2$ resistance furnace (figure 3) in N_2 atmosphere. The carbon dosage kept C/O mole ratio as 0.67, which can reduce 100% Ni and 60% Fe. And the temperature was adjusted by two Pt-30 mass%Rh/Pt-6 mass%Rh thermocouples to ensure the temperature error was <1°C before charging green pellets. After 30min, the corundum crucible would be quickly taken out and quenched with water to room temperature. Furthermore, every experiment would be done twice for the reproduction; the mineralogical observation and the chemical composition analysis were carried out.

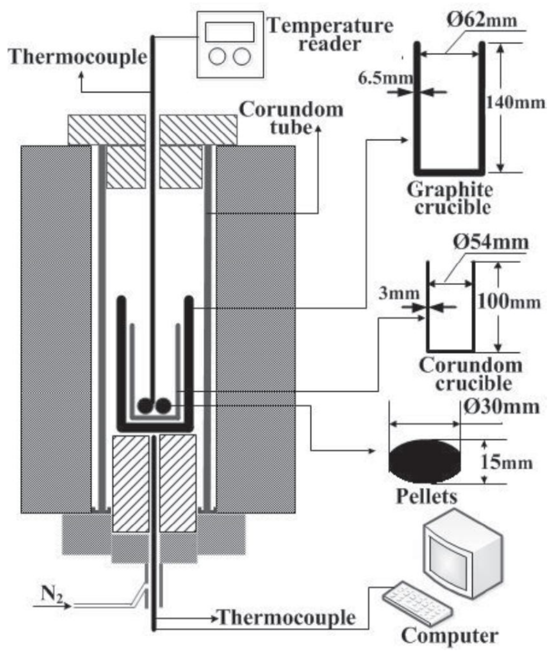

Figure 3: Schematic diagram of furnace

Table 2: Scheme of experiments on temperature

Basicity	**0.40**		**Time/min**	**30**
Temperature/℃	1380	1400	1420	1440

Table 3: Scheme of experiments on basicity

Temperature/°C	**1400**		**Time/min**		**30**
Basicity	0.40	0.45	0.50	0.55	0.60

3.2. Results and Discussion

The result in figure 4 showed that there was obvious separation between slag and metal within 30 min, the lamellar metal was placed on the slag with the increase of temperature, and after slightly artificial fragmentation, it was easy to get ferronickel granules or films under 3 mm by magnetic separation within 100~200Gs. And the mineral phase of cross section view of reduction samples were shown in figure 5, which indicated that the thickness of metal was approximate 0.1 ~ 0.4 mm, and part of slag was still packed with the metal; besides, it was evident that the agglomeration of metal would appear after 1400°C.

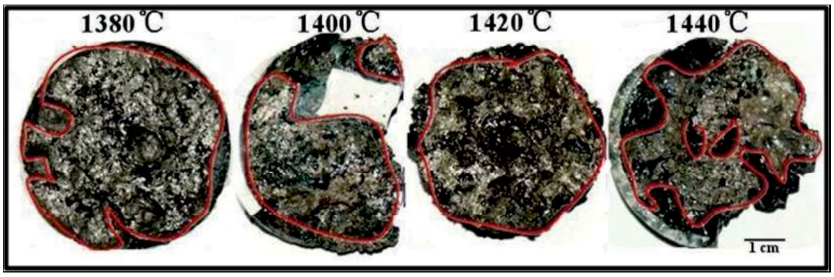

Figure 4: Morphology of laterite/coal pellets after reduction at 1380℃, 1400℃, 1420℃, 1440℃

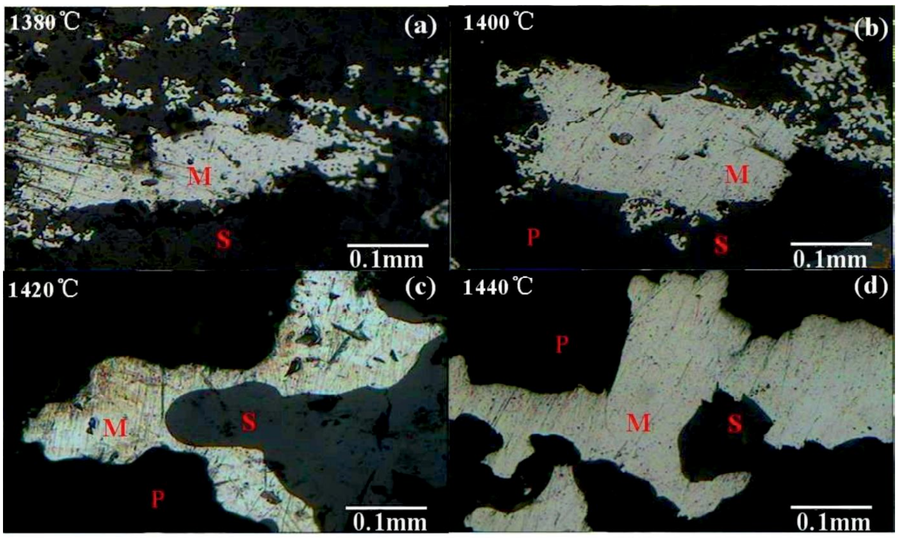

Figure 5: Cross section view of phases after reduction at 1380℃, 1400℃, 1420℃, 1440℃ (M-metal, S-slag, P-pore)

Then, at the same level of carbon dosage, the influence of CaO was investigated in accordance with former calculations from 0.40 to 0.60 at 1400°C. The mineral phase or morphology of reduction samples is shown in figure 6. Significant growth can be observed with more and more CaO addition, and when the basicity was 0.60, centimeter-level metal shell was formed on the surface and could be easily separated from the slag. Figure 7 showed the metal grade of Ni-Fe concentrate through magnetic separation, and the recovery ratio of nickel and iron were also obtained. It can be seen that both the Ni and Fe can be upgraded with the incensement of CaO, and it is worth to note that the recovery ratio of iron will be decreased nearly 30%, which means improvement of the nickel. When the quaternary basicity was 0.60 at 1400°C, the nickel grade could reach 12.63% and the recovery ratio was 96.21%, meanwhile, the iron grade was 81.1% and its recovery ratio was 62.96%.

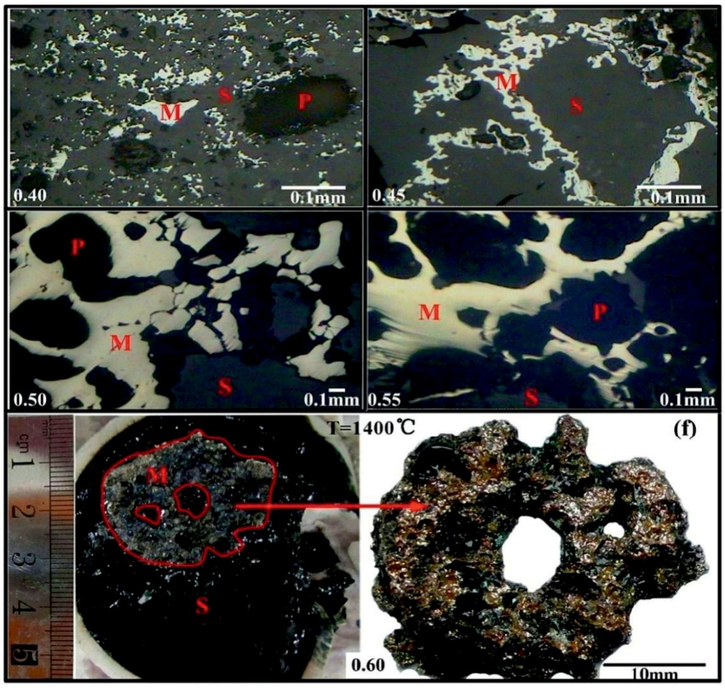

Figure 6: Phase and morphology of reduction samples with different amount of CaO at 1400℃ (M-metal, S-slag, P-pore)

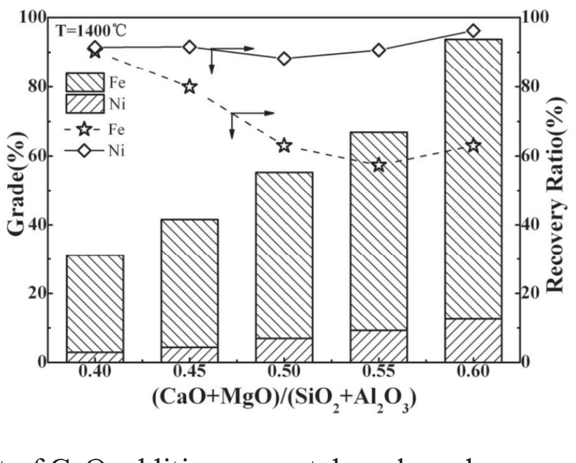

Figure 7: Effect of CaO addition on metal grade and recovery ratio at 1400℃

4. CONCLUSIONS

The formation of ferronickel nugget from laterite was studied in the present study. The conclusions can be summarized as follows:

(1) Temperature and the basicity are the primary factors to ensure the separation between metal and slag.

(2) The ferronickel nugget can be formed when the basicity is above 0.5 and the temperature is higher than 1400℃.

(3) The nickel content could reach 12.6% from the laterite with 1.8 nickel and the recovery ratio of nickel was 96% , while the recovery ratio of Fe is only about 63%

5. ACKNOWLEDGEMENT

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