

MATTE SEPARATED BEHAVIOR FROM SLAG DURING THE CLEANING PROCESS BY USING WASTE COOKING OIL AS CARBON NEUTRAL REDUCTANT

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Abstract

As a waste resource, waste cooking oil (WCO) has not been widely used. Based on the characteristics of WCO cracking, this study proposed to replace fossil-based reductant with WCO for copper slag cleaning, to solve the problem of carbon neutralization in this process. Copper slag cleaning experiments were carried out in a lab-scale electric furnace. The matte separated behavior from slag and the distribution of matte in slag were studied. The results showed that the Fe_3O_4 content decreases from 12.9 to 3.5 wt.% by injecting 2.2 mL of WCO into 300 g copper slag at 1250 °C. The distribution of copper content in slag is gradient along the vertical direction. In the reduction stage, the excessive Fe_3O_4 is reduced and the fluidity of slag is improved. When the precipitation time is above 60 minutes, the copper content in the middle and upper slag is reduced to 0.57 wt.%, which realizes the copper slag cleaning by using WCO.

Keywords: Waste cooking oil; Reductant; Copper slag; Matte

1. Introduction

Modern copper smelting by pyrometallurgical method mainly produces high-grade matte with oxygen-enriched air [1, 2], but under the condition of high oxygen potential, solid Fe_3O_4 would inevitably be produced in the slag. The high content of Fe_3O_4 would increase the viscosity of slag and increase the loss of copper in slag [3]. Slag is considered the secondary source of metal, and the metal in slag could be recovered by different methods [4, 5]. Copper and other precious metals could be effectively recovered during copper slag cleaning process [6, 7]. In industry, cleaning in an electric furnace [8-12] and flotation method [13-16] are mainly used to recover copper. Flotation involves treating the slag with chemicals that bind to the metal and cause hydrophobicity. Then, the foaming agent is added to the water bath, and the metal adsorbed by the bubble floats on the top of the bath under the hydrophobic effect [17, 18]. Although the flotation method has low energy consumption and high copper recovery, the water consumption of the flotation method is large, and the waste liquid may cause environmental pollution [16]. Because of the

advantages of high production efficiency and good adaptability of raw materials, copper slag cleaning in an electric furnace has been widely used in the copper industry. Copper slag cleaning in an electric furnace is to reduce the Fe_3O_4 content for improving the sedimentation conditions of matte particles by adding reductant [7]. Fossil-based reductants such as coke, pulverized coal, natural gas, and diesel oil are often used as reductants in the cleaning process. However, the application of these reductants would emit greenhouse gases and cause the increasing depletion of fossil energy. Therefore, the development of renewable and environmentally friendly reductants instead of traditional reductants is crucial.

Biomass energy as renewable clean energy has been gradually taken seriously [19-21]. All organic carbon present is derived from photosynthesis; biomass energy does not lead to an increase in carbon dioxide in the atmosphere, and therefore does not lead to the greenhouse effect [22]. The application of biomass energy in the field of metallurgy has gradually attracted the attention of relevant scholars. Zuo et al. [19] simplified biomass to C, CO, H_2 and CH_4 . The effects of reductant dosage and temperature

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on the reduction rate and product composition of copper slag were studied. The feasibility of reducing copper slag by biomass was analyzed theoretically. Kumar et al. [23] reduced iron oxide to metallic iron using biochar produced by cracking waste nut shell at high temperature as carbon source. The results show that biochar extracted from waste nut shell could be used as a valuable and renewable carbon resource for sustainable and clean ironmaking production. Guo et al. [24] used syngas produced during sawdust cracking as a reductant to produce iron ore pellets. The effects of reduction temperature and time on the reduction rate of iron ore pellets were studied, and the kinetics of the reduction process was analyzed. The results show that the reduction efficiency of syngas to iron ore pellets is like that of natural gas, which could reach more than 99%.

As a biomass resource, waste cooking oil (WCO) would cause environmental pollution without proper treatment before discharge, such as water resources and air pollution. The preparation of biodiesel from WCO has an obvious cost and environmental benefits, so it is the main research direction of resource utilization of WCO [25-30]. Some scholars have studied the preparation of surfactants [31] and syngas [32] from WCO, but the research and development of the products downstream of these industry chains are still lacking. In addition, these applications generally require complex processing of WCO, which reduces the convenience of the utilization. The products of high temperature cracking of WCO are mainly composed of H_2 , CO , CO_2 , and CH_4 , of which H_2 accounts for more than 70 vol.% [33]. Therefore, from the perspective of chemical composition, WCO could be used for the reduction of the copper slag, which could provide a new way for the resource utilization of WCO.

Previous research [34] indicated that copper slag cleaning could be realized by using WCO as a reductant, and the copper content in the slag could be reduced to less than 0.57 wt.%. However, the matte separated behavior from slag and the distribution of matte in slag need to be further investigated. Firstly, the thermodynamic analysis and experiments of copper slag cleaning by using WCO were carried out. On this basis, the copper slag cleaning process is divided into two stages: injection WCO stage and sedimentation stage. The matte separation from slag

behavior was investigated. And the distribution of matte particles in the slag during the cleaning process was analyzed. Where possible, the results obtained from this study may promote the industrial application of WCO for copper slag cleaning in an electric furnace.

2. Experimental

2.1. Materials

The slag sample used in the experiment was a smelting copper slag produced from the ISASMELT smelting furnace. ISASMELT furnace is periodic tapping matte and slag. The mixture in the early tapping stage is mainly matte, and the mixture in the later tapping stage is mainly slag. The raw materials studied in this paper are the mixture of slag and matte in the chute after tapping. Before the experiment, the copper slag sample was crushed and ground to pass the 60-mesh sieve.

The main chemical composition of the copper slag is shown in Table I. The compositions of the copper slag were detected by chemical analysis methods. For different components, different analysis methods were used. The copper content was determined by atomic absorption spectrometry (AAS, SHIMADZU, AA-6300C, Japan) with an accuracy of $\pm 0.5\%$ of the measured value. The iron content in slag adopted potassium dichromate titration method to detect with an accuracy of $\pm 0.45\%$ of the measured value; silica content was measured by gravimetric method with an accuracy of $\pm 0.5\%$ of the measured value; magnesium oxide and calcium oxide were measured by complexometric titration with an accuracy of $\pm 0.3\%$ of the measured value. The copper content in the slag is 17.82 wt.%, and the total content of Fe content is 33.06 wt.%. The magnetic analysis results show that the content of Fe_3O_4 in copper slag is 12.9 wt.%.

The WCO was collected in a local restaurant, the water and impurities were removed before the experiment. Firstly, the WCO was heated to 60 °C, and the oil and water were naturally stratified due to the difference of density, and then the water in the lower layer was removed. Table II lists the results of WCO element analysis after pretreatment. WCO is mainly composed of C, H, and O elements, and the contents of C and H elements account for more than 90% of the total quality. Due to dehydration

Table 1. Main chemical composition of the copper slag

Component	Cu	Fe (Total)	SiO_2	S	Al_2O_3	CaO	MgO	Zn	Fe_3O_4
Content Wt.%	17.82	33.06	19.13	8.07	2.96	2.12	1.95	1.83	12.9

Table 2. Element analysis of waste cooking oil

Element	C	H	O	N	S
Content Wt.%	77.81	12.33	8.93	0.86	0.07



pretreatment, the moisture in the WCO is only 0.54 wt.%.

2.2. Experimental method

Reduction experiments were carried out in a vertical tube furnace. The vertical tubular furnace was designed by our group and manufactured by Henan Chengyi Laboratory Equipment Co., Ltd. Figure 1 shows the schematic diagram of the experimental equipment. First of all, the corundum crucible containing 300 g copper slag sample was put into the furnace. The air in the furnace was discharged by a small vacuum pump, then 100 mL/min nitrogen was used as the protective gas, and the lance made of corundum was inserted into the copper slag through the hole in the middle of the flange to heat up with the furnace. When the reaction furnace reached 1250 °C at a heating rate of 10 °C/min for 40 minutes, the injection carrier gas (3 L/min) and the peristaltic pump of WCO were opened simultaneously. Under the action of carrier gas, the WCO was successfully injected into the copper slag for reaction. After injection, the carrier gas and peristaltic pump were turned off, and the lance was raised out of the furnace. After injecting WCO or holding for a certain time, the support platform of the experimental device was put down for taking out the crucible with pliers, and then put it into a water cooler equipped with normal temperature tap water for rapid cooling. The purpose of rapid cooling is to ensure that the slag and matte in the crucible remain in the physicochemical properties of a high temperature melting state, to better observe the experimental phenomenon and analysis of the experimental results. Then the slag was cut according to the longitudinal section (upper layer, middle layer, and lower layer), and each layer was analyzed in detail.

2.3. Analytical method

The copper slag sample was ground in a grinding machine (XZM-100, Wuhan Exploring Machinery, China). Then the magnetite content was determined by a magnetic analyzer (Satmagan S135, Rapiscan Systems, Finland) with an accuracy of ± 0.4 wt.% of the measured value. The microstructure of the material was analyzed by electron probe X-ray microanalysis (EPMA, JEOL JXA 8230, Japan) and energy dispersive spectrometer (EDS, UltraDry, USA). The viscosity of copper slag samples was analyzed by a high temperature viscometer (Rheotronic II, Theta, USA).

3. Results and discussion

3.1. Thermodynamic analysis of copper slag cleaning by WCO

The copper slag used in the experiment is fayalite-based copper slag which is mainly composed of iron oxides (FeO and Fe_3O_4) and SiO_2 . Figure 2 is a ternary diagram of $\text{FeO}-\text{Fe}_3\text{O}_4-\text{SiO}_2$ at 1250 °C. According to the chemical composition of the slag, the composition position is located in the liquid, spinel and SiO_2 coexistence phase ($\text{Liq} + \text{Spinel} + \text{SiO}_2$). This finding indicates that the copper slag would precipitate the spinel phase dominated by Fe_3O_4 at 1250 °C, which would increase the viscosity of the slag. The aggregation and sedimentation conditions of matte particles are deteriorated [35]. To improve the slag fluidity, it is necessary to move the composition point of the slag to the liquid phase zone (Slag-Liq) by reducing the Fe_3O_4 . While Fe_3O_4 decreases, the activity of FeO increases correspondingly, and combines with SiO_2 to form fayalite to avoid the precipitation of SiO_2 crystals.

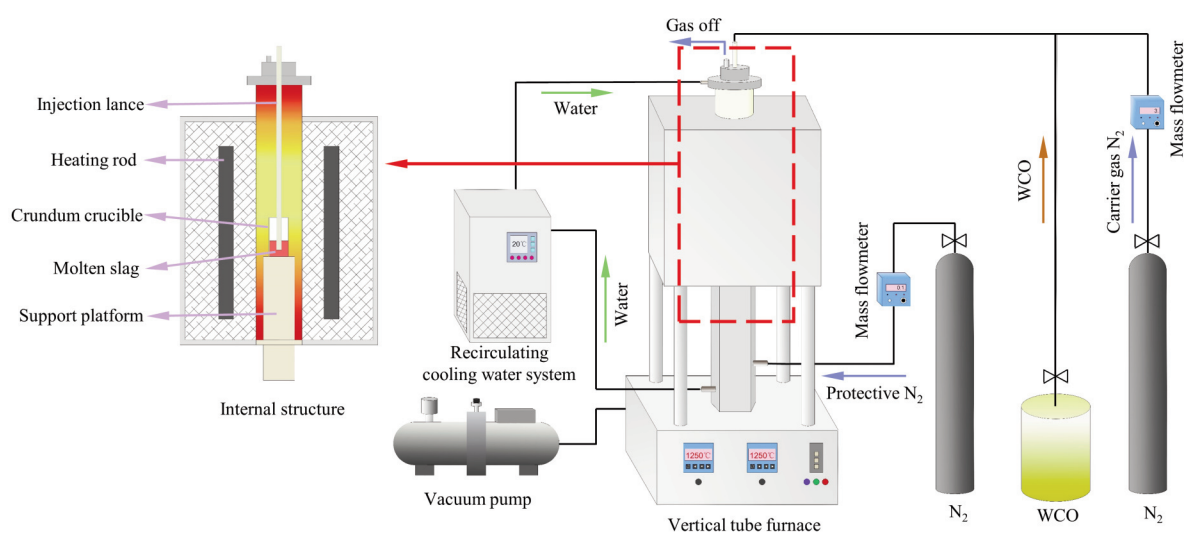


Figure 1. Schematic diagram of the experimental equipment



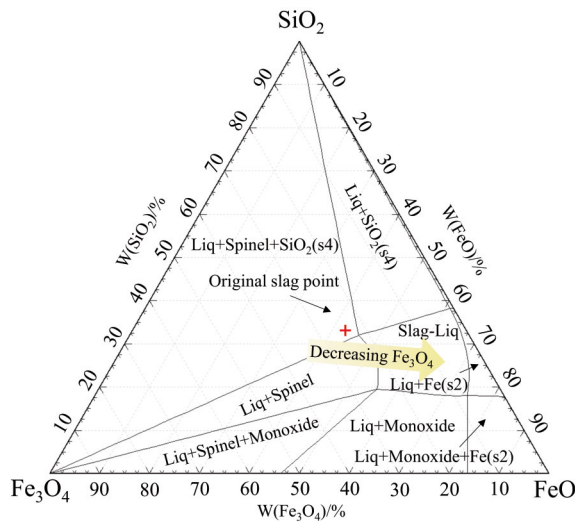
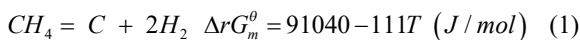
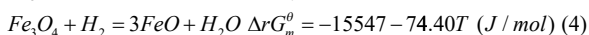
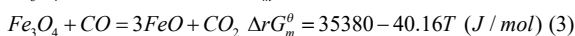
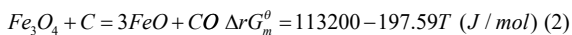


Figure 2. Ternary diagram of $\text{FeO-Fe}_3\text{O}_4\text{-SiO}_2$ at $1250\text{ }^\circ\text{C}$

The essence of the copper slag cleaning process is to reduce the excess Fe_3O_4 in the slag to FeO ; then, the FeO combines with SiO_2 to form a low melting point Fe_2SiO_4 to decrease the slag viscosity, which provides a good condition for the sedimentation of matte particles as a result. The WCO injected into the molten pool is pyrolyzed at high temperatures to produce reductive products such as H_2 , CO , CH_4 , and C . Secondary cracking of CH_4 would occur at high temperatures [36]. Equation (1) shows the total reaction formula of CH_4 cracking, and the final product is H_2 and elemental carbon.



Equation (2)–(4) shows the reaction of C , CO and H_2 with Fe_3O_4 in the slag.



At the smelting temperature of $1250\text{ }^\circ\text{C}$, the Gibbs free energies changes for all the reactions are negative, indicating that the CH_4 , C , CO , and H_2 produced by the cracking of WCO could reduce Fe_3O_4 in the slag to FeO .

3.2. Effect of injecting N_2 and WCO on matte sedimentation

3.2.1. Injecting N_2

After holding at $1250\text{ }^\circ\text{C}$ for 40 minutes, the copper slag was directly stirred by N_2 for 30 seconds (flow rate: 3 L/min). The sample of copper slag after injection nitrogen is shown in Figure 3. The slag sample shows stratification. This is because the

stirring of the melt drives the matte particles to collide and aggregate with each other. Ultimately, a part of the matte settles at the bottom of the crucible [37]. Many matte particles (brick red particles in Figure 3) are distributed both inside and on the surface of the slag layer. Without reductant, the melt is stirred directly by the carrier gas. The matte particles in the melt are mixed with the slag, part of the matte cannot settle to the bottom of the slag layer. The previous research work [38] shows that the main factor hindering the separation of slag and matte is the content of Fe_3O_4 .

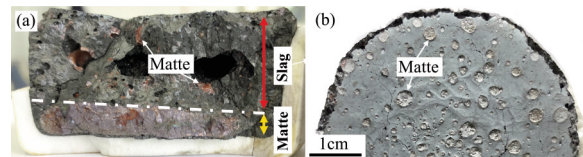


Figure 3. Image of the slag sample after injecting N_2 for 30s, (a) vertical section image; (b) upper surface image of slag

3.2.2. Injecting WCO

Under the same experimental parameters in addition to the addition of WCO, the sample of copper slag after injection for 30 seconds is shown in Figure 4. The structure of the slag layer is compact, the longitudinal height of the sample decreases, as shown in Figure 4a. The macroscopic matte particles in the copper slag disappear, and no obvious matte particles are found on the surface of the slag layer. These findings indicate that the addition of WCO promotes the sedimentation of matte particles. Then the reduced sample was cut uniformly, and the Fe_3O_4 and copper content in the upper, middle, and lower slag were analyzed. After the WCO was injected for 30 seconds, the Fe_3O_4 content in the copper slag decreased to 9.1wt.%, while the copper content in the upper, middle, and lower slag was 2.68, 3.27, and 4.74 wt.%, respectively.

The viscosities of original slag (Fe_3O_4 content about 12.9 wt.%) and reduced slag by WCO (Fe_3O_4 content about 3.0 wt.%) were measured by high temperature viscometer. Firstly, 50 g of the slag sample was prepared and transferred to an alumina crucible, which was put in the hearth of the viscosimeter. The crucible was then heated to $1290\text{ }^\circ\text{C}$ at a heating rate of $10\text{ }^\circ\text{C/min}$, keeping for 30 minutes. Then the alumina spindle was lowered to the slag layer for measuring the viscosity of the sample, and the viscosity data were measured from 1290 to $1160\text{ }^\circ\text{C}$ while recording by computer. The viscosity of reduced slag is lower than that of the original slag in the whole cooling process (Figure 5). This phenomenon verifies that the decrease of Fe_3O_4 would improve the fluidity of the copper slag and indirectly promote the separation of matte from slag.



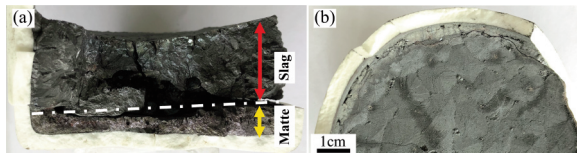


Figure 4. Image of slag sample after injecting WCO for 30 s, (a) vertical section image; (b) upper surface image of slag

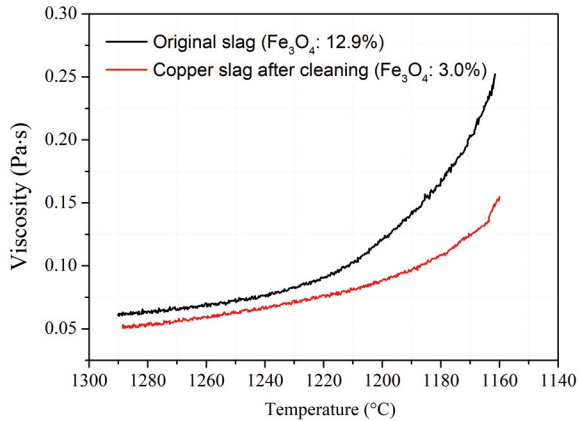


Figure 5. Viscosity change of slag before and after reduction

3.3. Matte separated from slag behavior

In the process of copper slag cleaning, in addition to the particle size, the factors affecting the sedimentation of matte particles in the slag are also related to the characteristics of slag [39, 40]. Reduction and sedimentation are two stages of the copper slag cleaning process, which are accompanied by the matte separation from slag. Therefore, the characteristics of the phase in the slag and the distribution of matte particles in the injection and sedimentation stages are investigated in detail below.

3.3.1. Injection stage

In this section, the variation of matte particle content in each slag layer during slag reduction was studied. The experiments were performed by controlling the injecting time of WCO (30, 60, 90, 120 s), and each sample after injecting was cooled rapidly. Figure 6 shows the content of Fe₃O₄ in copper slag after injecting WCO at a rate of 1.1 mL/min for different times. With prolonging injection time, the amount of WCO increases, which leads to the reduction of Fe₃O₄ content in copper slag. With the same injection time, the difference of Fe₃O₄ content between slag layers is small. For the upper slag, when the injection time increases from 30 to 60 seconds, the Fe₃O₄ content in the slag decreases from 9.1 to 7.2

wt.%. Further prolonging the duration to 120 seconds, the Fe₃O₄ content in the slag is reduced to 3.5 wt.%. Compared with the copper content in the slag after each injection, the matte particles in the slag show a gradient distribution. While the copper content in the upper layer of the slag is the lowest (Figure 7). The copper content in the upper, middle, and lower slag fluctuated between 1.65~2.68 wt.%, 2.49~3.27 wt.%, and 4.30~5.42 wt.%, respectively. The above phenomena show that during the process of injection WCO, the reduction of Fe₃O₄ and the sedimentation of matte particles occur simultaneously.

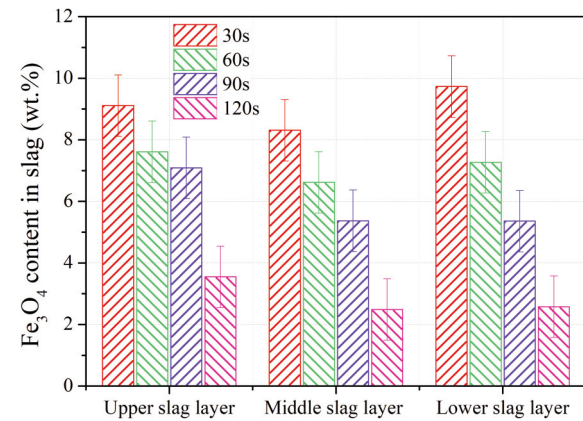


Figure 6. Magnetite content in each slag layer as a function of injecting WCO time

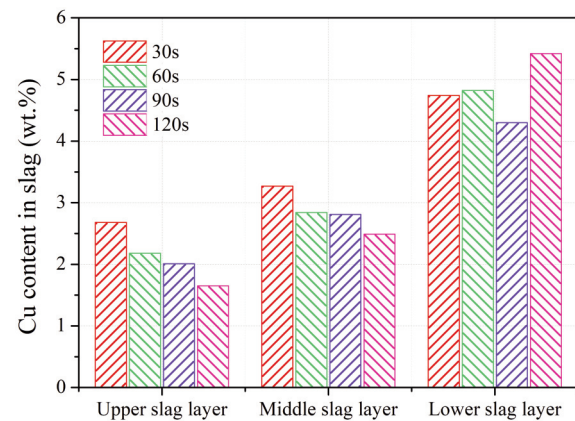


Figure 7. Copper content in each slag layer as a function of injecting WCO time

Figure 8 shows the cross-section and microstructure of the slag sample after injecting WCO for 30 seconds at 1250 °C. Four obvious phases of fayalite, Fe₃O₄, matte, and glass phases are observed in the copper slag. The content of Fe₃O₄ in the slag is approximately 9.1 wt.%, and the matte particles in the slag have adhered to the magnetite particles (Figure 8a'). As reported in the literature [38, 41], matte particles have good wettability with magnetite, and the sedimentation of matte particles is hindered after

they are attached to magnetite particles. From the microstructure, it could be seen that the number of matte particles in the reduced slag is less than that in the original copper slag, and the particle size is smaller. It is verified again that the matte is separated from the slag during the injection stage. Furthermore, the microstructure of the lower layer of copper slag is shown in Figure 8 c'. The matte particles with small size are distributed in the amorphous glass phase in the lower slag, indicating that part of matte particles cannot be sedimented completely in a short time. Based on the results of chemical analysis in Figure 7, the copper content in the lower slag layer in this experimental condition is 4.74 wt.%, while the matte observed in the microstructure of copper slag is less. This is mainly attributed to the part of the matte particles that would be adhered to the bottom of the copper slag, which is difficult to observe in the current microscopic region.

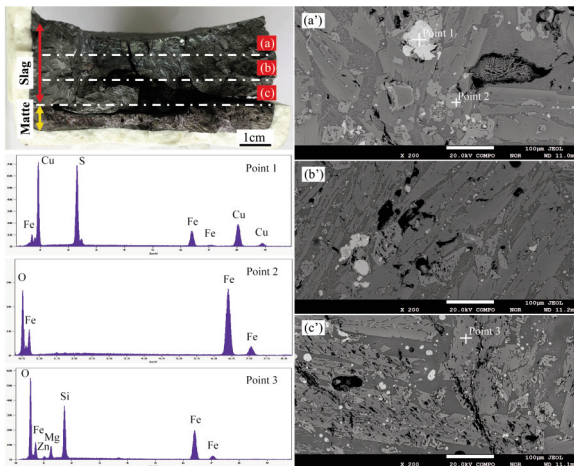


Figure 8. Cross-section and microstructure of the slag sample after reduction with WCO for 30 s: (a') upper layer; (b') middle layer; (c') lower layer

Figure 9 shows the cross-section and microstructure of the slag sample after injecting WCO for 120 seconds at 1250 °C. It is difficult to observe the Fe_3O_4 phase with large particles in each layer of copper slag, thus avoiding the phenomenon of matte particles attached to magnetite particles in the slag. However, there are still incomplete sedimentation matte particles in the upper, middle, and lower layers of copper slag, which are mainly distributed in the glass phase. Therefore, compared with Figure 8, increasing the amount of reductant, and prolonging the reaction time would only reduce the content of Fe_3O_4 . The copper content in the slag is still at a high level (> 2 wt.%) and has no obvious change.

3.3.2. Sedimentation stage

The copper content in the reduced slag is significantly lower than that of the original copper

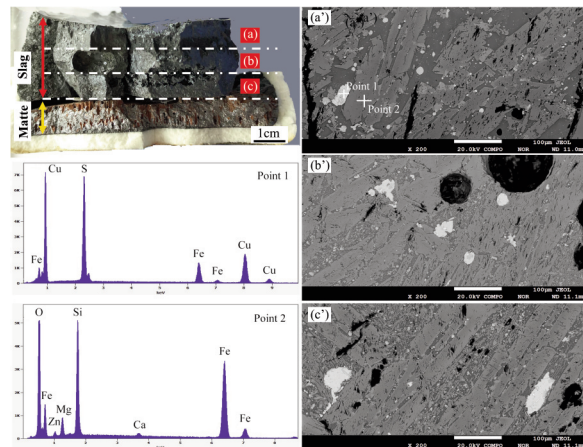


Figure 9. Cross-section and microstructure of the slag sample after reduction with WCO for 120 s: (a') upper layer; (b') middle layer; (c') lower layer

slag, due to the sedimentation of some matte particles in the injection WCO stage. However, in the process of injection, the turbulence of the melt makes some small matte particles stay in the slag. Although the Fe_3O_4 content is reduced by the WCO, the copper content in the slag is still high without sedimentation [42]. The slag was injected with WCO at the rate of 1.1 mL/min at 1250 °C for 2 minutes, then the injection of WCO and N_2 was stopped. The reduced copper slag was settled at high temperature for different time (0, 30, 60, 120 min). The whole experiment was carried out in N_2 atmosphere to prevent re-oxidation. The distribution and quantitative relationship of Fe_3O_4 and copper in each slag layer were analyzed.

The effect of sedimentation time on Fe_3O_4 content in each slag layer is shown in Figure 10. With the prolonging of sedimentation time, the content of Fe_3O_4 in the slag has no obvious change, and is maintained between 2 and 4 wt.%. The results indicate that the reduction of Fe_3O_4 is mainly concentrated in the injection WCO stage. Figure 11 shows the effect of sedimentation time on the copper content in each slag layer. From the overall trend analysis, the copper content in each slag layer decreases when the sedimentation time is prolonged. As the sedimentation time is extended to 60 minutes, the copper content in the middle and upper layer of the slag is 0.56 and 0.55 wt.%, respectively; while the copper content in the lower layer is 1.21 wt.%. Further prolonging the sedimentation time to 120 minutes, the copper content of each slag layer has no obvious change, the upper, middle, and lower layers are 0.56 wt.%, 0.57 wt.%, and 1.19 wt.%, respectively. The results indicate that the copper content in the slag decreases with the prolonging of sedimentation time. When the time is above 60 minutes, the slag tends to be stable, and the copper content in the middle and

upper layers remains at about 0.56%.

Chemical dissolution loss and physical entrainment loss are two types of copper loss in slag [43]. Because the main factor affecting the chemical dissolution loss is the physicochemical properties of slag; prolonging the time cannot reduce the chemical dissolution loss. Previous research work [34] explained that when the Fe_3O_4 content in this slag was reduced to 3 wt.%, there was still approximately 0.51 wt.% chemical dissolution copper loss in the slag. Moreover, Coursol et al. [44] pointed out that the physical entrainment loss (approximately 25 wt.%) and chemical dissolution loss (approximately 75 wt.%) still existed in the slag after copper slag cleaning. Therefore, it is difficult to reduce the copper content in the slag to less than 0.51 wt.% through copper slag cleaning without adjusting slag properties.

Figure 12 shows the cross-section and microstructures of the slag sample after reduction and sedimentation for 120 minutes. The slag and matte have a distinct stratification and the structure of

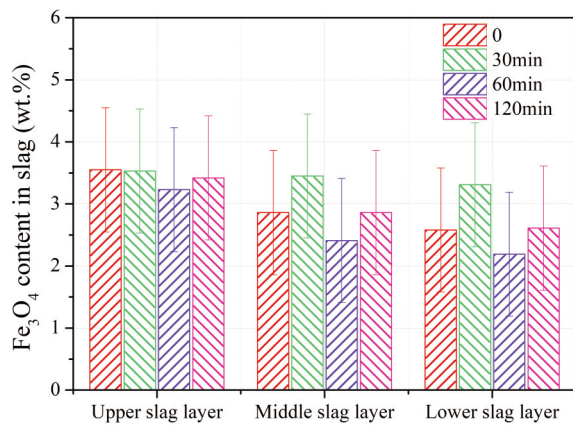


Figure 10. Magnetite content in each slag layer as a function of sedimentation time

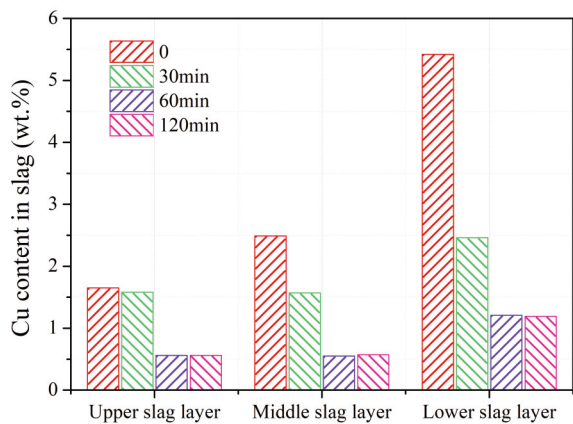


Figure 11. Copper content in each slag layer as a function of sedimentation time

molten slag is compact. The microstructure of each slag layer showed that the size of matte particles in the middle and upper slag was uniformly fine ($<10\ \mu\text{m}$), which was distributed in the glass phase. This is attributed to the precipitation of chemical dissolution copper during cooling. The copper content in the slag shown in Figure 11 was confirmed by SEM analysis. The copper content in the middle and upper layers of the slag is low, corresponding to 0.56 and 0.57 wt.%, respectively; and the copper content in the lower layer is relatively higher (1.19 wt.%). This is due to the direct contact between the lower slag and the matte layer, and some components in the slag react with matte to form SO_2 bubbles, while matte particles attached to the bubbles enter the slag layer with the rise of bubbles. It would increase the copper content of the lower slag [45]. In addition, some matte particles would adhere to the bottom of the slag layer, which also leads to a significant increase in the copper content of the lower slag.

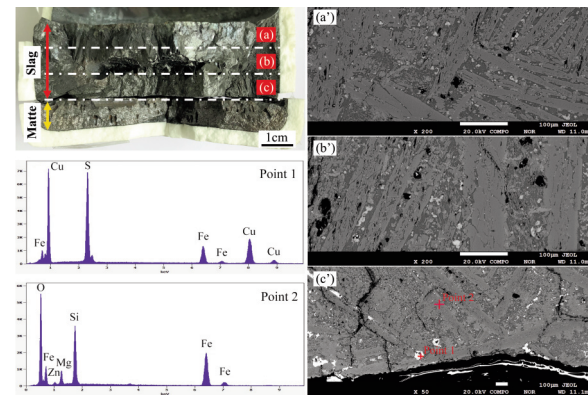


Figure 12. Cross-section and microstructure of the slag sample after reduction and sedimentation for 120 min; (a') upper layer; (b') middle layer; (c') lower layer

3.4. Separate mechanism of matte from slag by using WCO

Based on the experimental results, the separation behavior of matte from the copper slag during the cleaning process using WCO as a reductant could be expressed in Figure 13. The process of reduction and sedimentation transformation of the matte particles could be described as follows. When the WCO is injected into the copper slag, it is first cracked at high temperatures to produce reductants such as H_2 , CO , and CH_4 . These reductants contact with iron oxides, and the reduction occurs. The Fe_3O_4 was reduced to FeO , which was combined with SiO_2 in the slag to form fayalite. The melting point of fayalite is lower than that of magnetite, so the melt fluidity could be improved. The N_2 and reducing gas drive the melt to stir, which increases the collision probability of small

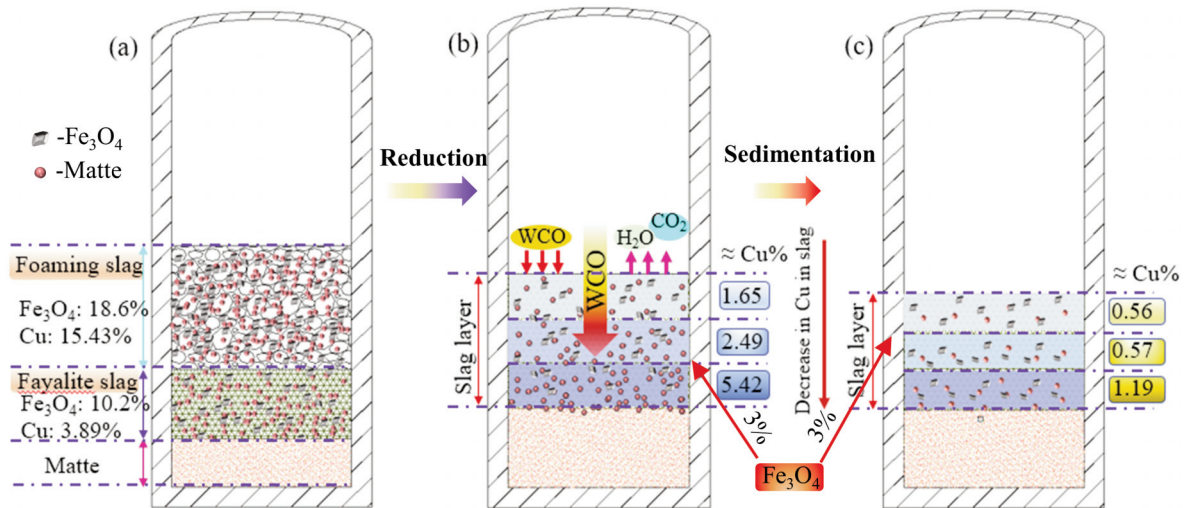


Figure 13. Schematic diagram of the copper slag cleaning process by using WCO, (a): direct sedimentation of copper smelting slag; (b): reduction for 2 min; (c): sedimentation for 120 min after reduction

matte particles and makes them accumulate, providing favorable conditions for further sedimentation of matte. With the progress of injection, the content of Fe_3O_4 in the slag decreases gradually, and the slag viscosity decreases obviously. At this time, the majority of the matte particles settled; and the remaining small matte particles are mixed in the slag with the melt stirring. The reduction reaction ended with the stopping of injection, and the copper slag cleaning enters the stage of high temperature sedimentation. Without chemical reaction and temperature changes, the Fe_3O_4 content and the slag viscosity remain unchanged in this stage. Based on the Stokes equation [46], the larger the particle size, the faster the sedimentation rate would be. The matte particles in the slag increase gradually from top to bottom. With the prolonging of the sedimentation time, the small matte particles mixed in the copper slag finally settle to the copper slag layer to realize the copper slag cleaning.

4. Conclusions

Injecting WCO in the slag could effectively reduce the content of Fe_3O_4 , thus reducing the viscosity of the slag and promoting the sedimentation of matte particles. In the copper slag cleaning process, the reduction of Fe_3O_4 in the slag mainly occurred in the WCO injection stage, and the majority of the matte particles were settled. 300 g of the copper slag was injected with WCO at 1.1 mL/min for 2 minutes at 1250 °C (carrier gas N_2 flow rate of 3 L/min), which reduced Fe_3O_4 in the slag from 12.9 wt.% to less than 3.5 wt.%. The copper content in the slag showed a gradient distribution with 1.65 wt.%, 2.49 wt.%, and 5.42 wt.% in the upper, middle, and lower layers of

the slag, respectively. In the sedimentation stage, the Fe_3O_4 content in the slag did not change significantly; while the sedimentation time was prolonged to more than 60 minutes, the slag tended to stabilize and the copper content in the middle and upper layers of the slag could be reduced to less than 0.57 wt.%, which reached the level of industrial slag discarding. The results of this study indicate that WCO could replace fossil-based reductants as a carbon neutral reductant, providing a new way for copper slag cleaning and WCO resource utilization.

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PONAŠANJE KAMENCA IZDVOJENOG IZ ŠLJAKE TOKOM PROCESA PREČIŠĆAVANJA POMOĆU OTPADNOG JESTIVOG ULJA KAO UGLJENIK NEUTRALNOG REDUCENTA

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Apstrakt

Otpadno jestivo ulje (WCO) je resurs koji nije u širokoj upotrebi. Na osnovu karakteristika krekovanja otpadnog jestivog ulja, u ovom radu se predlaže da se za prečišćavanje bakarne šljake umesto fosilnih reducenata koristi otpadno jestivo ulje da bi se u ovom procesu rešio problem neutralizacije ugljenika. Eksperimenti prečišćavanja bakarne šljake izvedeni su u laboratorijskoj električnoj peći. Ispitivano je ponašanje kamenca izdvojenog iz šljake, kao i distribucija kamenca u šljaci. Rezultati su pokazali da se sadržaj Fe_3O_4 smanjuje sa 12.9 na 3.5 wt.% ubacivanjem 2.2 mL WCO u 300 g bakarne šljake na 1250 °C. Distribucija sadržaja bakra u šljaci je gradijentna duž vertikale. U fazi redukcije, smanjuje se Fe_3O_4 i poboljšava tečljivost šljake. Kada je vreme taloženja duže od 60 minuta, sadržaj bakra u srednjem i gornjem sloju šljake se smanjuje na 0.57 wt.%, čime se ostvaruje prečišćavanje bakarne šljake pomoću otpadnog jestivog ulja.

Cljučne reči: Otpadno jestivo ulje; Reducent; Bakarna šljaka; Kamenac

