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METHOD AND SYSTEM FOR RESOURCE UTILIZATION OF LATERITIC NICKEL ORE LEACHING TAILINGS

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ABSTRACT

The present disclosure discloses a method and system for resource utilization of lateritic nickel ore leaching tailings. The method includes: mixing the lateritic nickel ore leaching tailings with a flux to obtain a mixed material; performing a melting and slagging
5 desulfurization on the mixed material to obtain slag and flue gas containing SO₂; and mixing the slag with a reducing agent for reduction and iron extraction to obtain molten iron, iron extraction slag and coal gas.

METHOD AND SYSTEM FOR RESOURCE UTILIZATION OF LATERITIC NICKEL ORE LEACHING TAILINGS

PRIORITY INFORMATION

[0001] The present disclosure claims the priority to Chinese patent application No. 202311301553.6, titled “Method and System for Resource Utilization of Lateritic Nickel Ore Leaching Tailings”, filed on October 09, 2023 to China National Intellectual Property Administration, the disclosures of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] The present disclosure belongs to the technical field of solid waste utilization, and particularly relates to a method and system for resource utilization of lateritic nickel ore leaching tailings.

BACKGROUND

[0003] Nickel has the characteristics of high mechanical strength, good ductility, infusibility, high temperature resistance, high chemical stability, etc. It is widely used in the field of stainless steel, new energy, etc., and has become an indispensable metal in current society. In recent years, with the progress of the technology, the recovery of nickel and cobalt from lateritic nickel ore with high iron and low magnesium by high pressure sulfuric acid leaching technology has attracted much attention, and the production capacity has increased year by year.

[0004] The biggest bottleneck of wet leaching of the lateritic nickel ore is the large amount of tailings. The iron in the tailings mainly exists in the form of hematite. Due to its high water content, low grade and high sulfur content, the tailings cannot be directly sold to iron and steel plants as raw materials for iron making. At present, there is no industrial example of comprehensive recycling and utilization. The tailings are basically treated by stacking, which

has extremely high environmental safety hazards.

SUMMARY

[0005] The present disclosure aims to solve one of technical problems in the related art at least to a certain extent. To this end, a purpose of the present disclosure is to provide a method and system for resource utilization of lateritic nickel ore leaching tailings. The method can not only solve the problem of environmental protection hazards of the lateritic nickel ore leaching tailings, but also can comprehensively utilize the valuable elements such as iron and sulfur therein, resulting in considerable economic benefits.

[0006] In the first aspect of the present disclosure, the present disclosure provides a method for resource utilization of lateritic nickel ore leaching tailings. According to embodiments of the present disclosure, the method includes:

(1) mixing the lateritic nickel ore leaching tailings with a flux to obtain a mixed material;

(2) performing a melting and slagging desulfurization on the mixed material to obtain slag and flue gas containing SO₂; and

(3) mixing the slag with a reducing agent for reduction and iron extraction to obtain molten iron, iron extraction slag and coal gas.

[0007] In the method for resource utilization of lateritic nickel ore leaching tailings according to the above embodiment of the present disclosure, the lateritic nickel ore leaching tailings are used as raw material to solve the problem of the environmental protection hazards of the lateritic nickel ore leaching tailings. The lateritic nickel ore leaching tailings are mixed with the flux to obtain the mixed material. The mixed material is subjected to a melting and slagging desulfurization to obtain slag and flue gas containing SO₂, wherein the flue gas containing SO₂ can be used for making acid to realize the comprehensive utilization of sulfur element in the lateritic nickel ore leaching tailings; the slag can be subjected to reduction to extract iron to obtain the molten iron, iron extraction slag and coal gas; the obtained molten iron can be used for steelmaking; the comprehensive utilization of iron element in the lateritic nickel ore leaching tailings can be achieved; the obtained iron extraction slag can be used for preparing building raw material; and the obtained coal gas can be used as fuel, thereby

producing objective economic benefits. Moreover, the lateritic nickel ore leaching tailings are mixed with the flux before the melting and slagging desulfurization, which can directly adjust the internal structure and the chemical compositions of the slag, improve the metallurgical properties of the slag, reduce the temperature of reduction and iron extraction, and facilitate subsequent reduction and iron extraction. In addition, the melting and slagging desulfurization and the reduction and iron extraction are performed separately. On the one hand, because more heat is required for melting and slagging desulfurization, and less heat is required for reduction and iron extraction, energy consumption can be reduced and production and operating cost can be decreased. On the other hand, a weak reducing atmosphere is used for desulfurization and melting, which is conducive to achieve the decomposition of gypsum and solve the problems that it is difficult to adapt to the composition fluctuation of the lateritic nickel ore leaching tailings due to the narrow mixing range of the reducing agent (too much or too little reducing agent is not conducive to desulfurization) and the problem of bond caused by too high temperature of reduction and desulfurization during conventional reduction and desulfurization. Thus, the method can solve the problem of the environmental protection hazards in the lateritic nickel ore leaching tailings, comprehensively utilize the valuable elements therein such as iron and sulfur, and produce considerable economic benefits, and is low in energy consumption, low in production cost, simple in process, easy to operate, which is suitable for large-scale production and has high in practical value.

[0008] In addition, the method for resource utilization of lateritic nickel ore leaching tailings according to the above embodiment of the present disclosure may also have the following additional technical features.

[0009] In some embodiments of the present disclosure, the lateritic nickel ore leaching tailings are pre-dried before the lateritic nickel ore leaching tailings and the flux are mixed, which is conducive to subsequent distribution and transportation.

[0010] In some embodiments of the present disclosure, in step (1), drying and crushing are performed after the lateritic nickel ore leaching tailings and the flux are mixed, which is conducive to increase the efficiency of subsequent melting and slagging desulfurization and reduce the energy consumption of chemical material.

[0011] In some embodiments of the present disclosure, in step (1), the flux comprises CaO

and MgO, which is conducive to the progress of reduction and iron extraction.

[0012] In some embodiments of the present disclosure, in step (1), the lateritic nickel ore leaching tailings and the flux are mixed at a ratio enabling a mass ratio of CaO to SiO₂ in the iron extraction slag to be (0.9-1.2): 1, and a content of MgO in the iron extraction slag to be 6 wt% to 10wt%, which is conducive to the progress of reduction and iron extraction.

[0013] In some embodiments of the present disclosure, in step (2), a temperature of the melting and slagging desulfurization ranges from 1500°C to 1550°C.

[0014] In some embodiments of the present disclosure, the ends of a first fuel spray lance and a mixed material spray lance extend below the slag during the melting and slagging desulfurization, which is conducive to the progress of melting and slagging desulfurization.

[0015] In some embodiments of the present disclosure, combustion-supporting air adopted by the first fuel spray lance includes oxygen-enriched air, a concentration of oxygen in the oxygen-enriched air being not less than 65 vol%, and an excess air coefficient ranging from 0.95 to 0.98.

[0016] In some embodiments of the present disclosure, in step (3), a temperature of the reduction and iron extraction ranges from 1400°C to 1500°C.

[0017] In some embodiments of the present disclosure, an end of a second fuel spray lance extends below a slag layer in the process of reduction and iron extraction, which is conducive to the progress of reduction and iron extraction.

[0018] In some embodiments of the present disclosure, the reduction and iron extraction is supplemented with heat by a third fuel spray lance and/or an electrode.

[0019] In some embodiments of the present disclosure, when the reduction and iron extraction is supplemented with heat by a third fuel spray lance, the end of the third fuel spray lance extends below the slag layer, and the volume of CO in a reaction system accounts for not less than 80% of the total volume of CO and CO₂, which can improve the reduction effect and reduce the iron content of the iron extraction slag.

[0020] In some embodiments of the present disclosure, the mixed material is pre-heated in advance before the mixed material is subjected to the melting and slagging desulfurization, which can improve the efficiency of subsequent melting and slagging desulfurization and reduce the energy consumption of the chemical material.

[0021] In some embodiments of the present disclosure, a temperature of the preheated mixed material ranges from 500°C to 650°C, which can improve the efficiency of subsequent melting and slagging desulfurization, reduce the energy consumption of the chemical material and avoid the decomposition of sulfate in advance.

5 **[0022]** In the second aspect of the present disclosure, the present disclosure provides a system for resource utilization of lateritic nickel ore leaching tailings. According to embodiments of the present disclosure, the system includes:

a mixing device having an inlet for the lateritic nickel ore leaching tailings, a flux inlet, and, a mixed material outlet, the mixing device being adapted to mix the lateritic nickel ore
10 leaching tailings with a flux to obtain a mixed material;

a melting and slagging desulfurization device having a mixed material inlet, a slag outlet and a flue gas outlet, the mixed material inlet being connected with the mixed material outlet, and the melting and slagging desulfurization device being adapted to perform a melting and slagging desulfurization on the mixed material to obtain slag and flue gas containing SO₂; and

15 a reducing device having a slag inlet, a reducing agent inlet, a molten iron outlet, an iron extraction slag outlet, and a coal gas outlet, the slag inlet being connected with the slag outlet, and the reducing device being adapted to mix the slag with a reducing agent for reduction and iron extraction to obtain molten iron, iron extraction slag, and coal gas.

[0023] In the system for resource utilization of lateritic nickel ore leaching tailings
20 according to the above embodiment of the present disclosure, the lateritic nickel ore leaching tailings are used as raw material to solve the problem of the environmental protection hazards of the lateritic nickel ore leaching tailings. The lateritic nickel ore leaching tailings are mixed with the flux by a mixing device to obtain the mixed material. The mixed material is subjected to a melting and slagging desulfurization by a melting and slagging desulfurization device to
25 obtain slag and flue gas containing SO₂, wherein the flue gas containing SO₂ can be used for making acid to realize the comprehensive utilization of sulfur element in the lateritic nickel ore leaching tailings; the slag can be reduced by the reducing device to extract iron to obtain molten iron, iron extraction slag and coal gas; the obtained molten iron can be used for steelmaking; the comprehensive utilization of iron element in the lateritic nickel ore leaching tailings can be
30 achieved; the obtained iron extraction slag can be used for preparing building raw material; and

the obtained coal gas can be used as fuel, thereby producing objective economic benefits. Moreover, the mixing device is provided with the inlet for the lateritic nickel ore leaching tailings, the flux inlet and the mixed material outlet; the melting and slagging desulfurization device is provided with a mixed material inlet connected with the mixed material outlet; and the lateritic nickel ore leaching tailings are mixed with the flux before the melting and slagging desulfurization, which can directly adjust the internal structure and the chemical compositions of the slag, improve the metallurgical properties of the slag, reduce the temperature of reduction and iron extraction, and facilitate subsequent reduction and iron extraction. In addition, melting and slagging desulfurization and reduction and iron extraction are performed in different apparatuses respectively. On the one hand, because more heat is required for melting and slagging desulfurization, and less heat is required for reduction and iron extraction, energy consumption can be reduced and production and operating cost can be decreased. On the other hand, a weak reducing atmosphere is used for desulfurization and melting, which is conducive to achieve the decomposition of gypsum and solve the problems that it is difficult to adapt to the composition fluctuation of the lateritic nickel ore leaching tailings due to the narrow mixing range of the reducing agent (too much or too little reducing agent is not conducive to desulfurization) and the problem of bond caused by too high temperature of reduction and desulfurization during conventional reduction and desulfurization. Thus, the system can solve the problem of the environmental protection hazards in the lateritic nickel ore leaching tailings, comprehensively utilize the valuable elements therein such as iron and sulfur, and produce considerable economic benefits, and is low in energy consumption, low in production cost, simple in process, easy to operation, which is suitable for large-scale production and has high in practical value.

[0024] In addition, the system for resource utilization of lateritic nickel ore leaching tailings according to the above embodiment of the present disclosure may also have the following additional technical features.

[0025] In some embodiments of the present disclosure, the system further includes a pre-drying treatment device; wherein: the pre-drying treatment device has a lateritic nickel ore leaching tailings inlet and a dried leaching tailings outlet connected with the lateritic nickel ore leaching tailings inlet; and the pre-drying treatment device is adapted to pre-dry the lateritic

nickel ore leaching tailings before the lateritic nickel ore leaching tailings are mixed with the flux, which is conducive to subsequent distribution and transportation.

[0026] In some embodiments of the present disclosure, the system further includes a drying and crushing device; wherein: the drying and crushing device has an inlet for a material to be treated and an outlet for a dried and crushed material, the inlet for the material to be treated being connected with the mixed material outlet; and the outlet for the dried and crushed material being connected with the mixed material inlet; and the drying and crushing device is adapted to dry and crush the mixed material before the mixed material is supplied to the melting and slagging desulfurization device; and supply the dried and crushed mixed material obtained to the melting and slagging desulfurization device, which improves the efficiency of subsequent melting and slagging desulfurization and reduces the energy consumption of the chemical material.

[0027] In some embodiments of the present disclosure, the system further includes: a preheating device, wherein, the preheating device has a mixed material inlet, a preheated material outlet and a preheated tail gas outlet; the mixed material inlet being connected with the mixed material outlet; the preheated material outlet being connected with the mixed material inlet; and the preheating device being suitable for preheating the mixed material before the mixed material is supplied to the melting and slagging desulfurization device; and supply the preheated mixed material to the melting and slagging desulfurization device; and a dust collecting device, the dust collecting device has a preheated tail gas inlet, a dust collecting outlet and an outlet for tail gas after dust collection; the preheated tail gas inlet being connected with the preheated tail gas outlet; the dust collecting outlet being connected with the mixed material inlet; and the outlet for the tail gas after dust collection being connected with the pre-drying treatment device, which is conducive to increase the efficiency of subsequent melting and slagging desulfurization and reduce the energy consumption of the chemical material.

[0028] In some embodiments of the present disclosure, the melting and slagging desulfurization device includes: a melting and slagging desulfurization device body including a furnace and a slag region from top to bottom; a mixed material spray lance having an end extending into the slag region; a first fuel spray lance having an end extending into the slag region; a secondary tuyere arranged on the furnace; a flue duct in communication with the

furnace; and a slag outlet arranged on a side wall of the slag region. Thus, the comprehensive utilization of sulfur element in the lateritic nickel ore leaching tailings is realized.

[0029] In some embodiments of the present disclosure, the melting and slagging desulfurization device further includes a flue gas waste heat recovery device connected with the flue. Thus, the heat utilization rate of the whole process can be increased and the energy consumption can be reduced.

[0030] In some embodiments of the present disclosure, the reducing device includes: a reducing device body, having, along a horizontal direction, a reducing region, a carburizing region and a settling region arranged, a partition wall being arranged between the carburizing region and the settling region, and a bottom end of the partition wall being spaced apart from a bottom of the reducing device body by a distance; a slag inlet arranged in the reducing region; a reducing agent arranged in the reducing region; a second fuel spray lance arranged in the reducing region and having an end extending below the slag layer of the reducing region; a carburizing agent spray lance arranged in the carburizing region and having an end extending into the slag layer of the carburizing region; and a heat supplementing device arranged in the carburizing region and the settling region. Thus, the comprehensive utilization of iron element in the lateritic nickel ore leaching tailings is realized.

[0031] In some embodiments of the present disclosure, the system further includes a coal gas utilization device; wherein the coal gas utilization device is connected with the coal gas outlet, the pre-drying treatment device, the preheating device and the melting and slagging desulfurization device; and the coal gas utilization device is adapted to collect and supply the the coal gas generated in the reducing device, as fuel, to at least one of the pre-drying treatment device, the preheating device and the melting and slagging desulfurization device. Thus, it can improve the utilization efficiency of coal gas and the heat utilization rate of the entire technology, thereby reducing energy consumption.

[0032] In some embodiments of the present disclosure, a top of the slag region is spaced apart from a bottom of the melting and slagging desulfurization device body by a distance not less than 800 mm; an end of the mixed material spray lance is spaced apart from the top of the slag region by a distance not less than 200 mm, and an end of the first fuel spray lance is spaced apart from the top of the slag region by a distance not less than 200 mm, which is conducive to

improve the melting efficiency.

[0033] In some embodiments of the present disclosure, an end of the second fuel spray lance is spaced apart from the top of the slag layer by a distance not less than 200 mm and is located above a molten iron layer.

5 **[0034]** The additional aspects and advantages of the present disclosure will be set forth in part in the following description, and in part will become apparent from the following description, or will be learned by the practice of the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0035] The above and/or additional aspects and advantages of the present disclosure will
10 become apparent and more readily appreciated from the description of the embodiments in combination with the following figures, wherein:

[0036] Fig. 1 is a flowchart of a method for resource utilization of lateritic nickel ore leaching tailings according to an embodiment of the present disclosure;

[0037] Fig. 2 is a structural schematic diagram of a system for resource utilization of
15 lateritic nickel ore leaching tailings according to an embodiment of the present disclosure;

[0038] Fig. 3 is a first structural schematic diagram of a melting and slagging desulfurization device according to an embodiment of the present disclosure;

[0039] Fig. 4 is a second structural schematic diagram of a melting and slagging desulfurization device according to an embodiment of the present disclosure;

20 **[0040]** Fig. 5 is a structural schematic diagram of a melting and slagging desulfurization device according to another embodiment of the present disclosure;

[0041] Fig. 6 is a structural schematic diagram of a system for resource utilization of lateritic nickel ore leaching tailings according to another embodiment of the present disclosure;

[0042] Fig. 7 is a first structural schematic diagram of a reducing device according to an
25 embodiment of the present disclosure;

[0043] Fig. 8 is a second structural schematic diagram of a reducing device according to an embodiment of the present disclosure;

[0044] Fig. 9 is a structural schematic diagram of a system for resource utilization of

lateritic nickel ore leaching tailings according to another embodiment of the present disclosure;

[0045] Fig. 10 is a structural schematic diagram of a system for resource utilization of lateritic nickel ore leaching tailings according to another embodiment of the present disclosure;

[0046] Fig. 11 is a structural schematic diagram of a system for resource utilization of

5 lateritic nickel ore leaching tailings according to another embodiment of the present disclosure;

[0047] Fig. 12 is a structural schematic diagram of a system for resource utilization of lateritic nickel ore leaching tailings according to another embodiment of the present disclosure;

and

[0048] Fig. 13 is a structural schematic diagram of a system for resource utilization of

10 lateritic nickel ore leaching tailings according to another embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0049] Embodiments of the present disclosure will be described below in detail. Examples of the embodiments are shown in the accompanying drawings, wherein the same or similar reference numerals refer to the same or similar elements or elements having same or similar functions throughout. The embodiments described below with reference to the drawings are
15 exemplary embodiments, and are intended to explain the present disclosure, and should not be understood as a limitation to the present disclosure.

[0050] In the description of the present disclosure, it should be understood that terms such as “central”, “longitudinal”, “transverse”, “length”, “width”, “thickness”, “upper”, “lower”,
20 “front”, “rear”, “left”, “right”, “vertical”, “horizontal”, “top”, “bottom”, “inner”, “outer”, “clockwise”, “counterclockwise”, “axial”, “radial”, “circumferential”, etc. indicate the direction or position relationships based on the direction or position relationships shown in the drawings, and are only intended to facilitate the description of the present disclosure and the simplification of the description rather than to indicate or imply that the indicated device or
25 element must have a specific direction or constructed and operated in a specific direction, and thus cannot be understood as a limitation to the present disclosure.

[0051] In addition, the terms such as “first” and “second” are only used for the purpose of description, rather than being understood to indicate or imply relative importance or implicitly

indicate the number of indicated technical features. Thus, the features limited with “first” and “second” can explicitly or impliedly include at least one of the features. In the description of the present disclosure, the meaning of “a plurality of” means at least two, for example two, three, etc., unless otherwise clearly specified.

5 **[0052]** In the present disclosure, unless otherwise specifically specified and defined, the terms such as “mounted”, “connected”, “connecting”, “fixed” and the like should be understood in broad sense, and for example, may be fixedly connected, or may be detachably connected, or integrated, may be mechanically connected, or may be electrically connected, and may be directly connected or indirectly connected by means of an intermediate medium may be inner
10 communication of two elements or interaction relationship of two elements unless otherwise clearly specified. For those ordinary skilled in the art, the specific meanings of the above terms in the present disclosure may be understood according to specific conditions.

[0053] In the present disclosure, unless otherwise clearly specified and limited, a first feature “above” or “below” a second feature may mean that the first feature and the second
15 feature are in direct contact, or the first feature and the second feature are in indirect contact through an intermediary. Moreover, the first feature “on”, “above” and “over” the second feature may mean that the first feature is directly above or obliquely above the second feature, or merely indicate that the horizontal height of the first feature is higher than that of the second feature. The first feature is “under”, “below” and “beneath” the second feature may mean that
20 the first feature is directly below or obliquely below the second feature, or may just indicate that the horizontal height of the first feature is lower than that of the second feature.

[0054] In a first aspect of the present disclosure, the present disclosure provides a method for resource utilization of lateritic nickel ore leaching tailings. According to embodiments of the present disclosure, referring to Fig. 1, the method includes the following.

25 **[0055]** S100: mixing the lateritic nickel ore leaching tailings with a flux.

[0056] In this step, the lateritic nickel ore leaching tailings are mixed with the flux to obtain the mixed material. Specifically, the lateritic nickel ore leaching tailings may be the tailings after filter pressing in a lateritic nickel ore wet leaching system (water content is 30 wt% to 45 wt%). Based on the dry basis of the lateritic nickel ore leaching tailings, the content of calcium
30 element in the lateritic nickel ore leaching tailings is not greater than 8 wt%, and the content of

iron element is 25 wt% to 50 wt% and the content of sulfur element is 3 wt% to 10 wt%. The flux includes CaO and MgO, which can be pure CaO and MgO, or various materials rich in CaO and MgO, such as limestone, dolomite, steel slag, high magnesium lateritic ore, etc. By mixing the lateritic nickel ore leaching tailings with the flux, the internal structure and the chemical compositions of the obtained slag can be adjusted to improve the metallurgical properties of the slag, and reduce the temperature of reduction and iron extraction, which is conducive to the process of reduction and iron extraction. Moreover, the lateritic nickel ore leaching tailings and the flux are mixed at a ratio enabling a mass ratio of CaO to SiO₂ in the iron extraction slag obtained by reduction and iron extraction to be (0.9-1.2): 1 of, and a content of of MgO in the iron extraction slag to be 6 wt% to 10 wt%.

[0057] According to the embodiment of the present disclosure, the lateritic nickel ore leaching tailings are pre-dried before the lateritic nickel ore leaching tailings are mixed with the flux, and the water content of the pre-dried lateritic nickel ore leaching tailings ranges from 15 wt% to 20 wt%, which is neither dusty nor clumped, and is conducive to the subsequent distribution and transportation. Moreover, the pre-drying can be performed by using a drying kiln and a dust collecting device. The drying kiln can adopt a steam dryer for indirect heat exchange (steam temperature $\geq 120^{\circ}\text{C}$) or a rotary drying kiln for direct heat exchange. For example, when the steam dryer is adopted, the heat source can be the steam generated in the process of waste heat recovery of flue gas in the subsequent step of melting and slagging desulfurization and the step of reduction and iron extraction, and the steam temperature is $\geq 120^{\circ}\text{C}$; when the rotary drying kiln is adopted, a cocurrent drying kiln is preferred; the hot air temperature is $\leq 700^{\circ}\text{C}$; the tail gas temperature ranges from 105°C to 120°C ; and the heat source of the rotary kiln can adopt pulverized coal, coal gas or high temperature tail gas.

[0058] S200: performing a melting and slagging desulfurization on the mixed material.

[0059] In this step, the mixed material is subjected to a melting and slagging desulfurization to obtain slag and flue gas containing SO₂. Specifically, the ends of a first fuel spray lance and a mixed material spray lance extend below the slag, and the oxygen-enriched air and the fuel enter below the slag by the first fuel spray lance for submerged combustion, to provide heat for the melting of the mixed material. The specific chemical reaction equations include $\text{C}_a\text{H}_b\text{O}_c\text{N}_d\text{S}_e + \text{O}_2 \rightarrow \text{CO} + \text{H}_2\text{O} + \text{N}_2 + \text{SO}_2$, and $\text{CO} + \text{O}_2 \rightarrow \text{CO}_2 \uparrow$. The mixed material enters below

the slag by the mixed material spray lance, and undergo the reactions of decomposition ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \uparrow$), desulfurization ($\text{Al}_2(\text{SO}_4)_3 + \text{CO} \rightarrow \text{Al}_2\text{O}_3 + \text{CO}_2 \uparrow + \text{SO}_2 \uparrow$, $\text{Fe}_2(\text{SO}_4)_3 + \text{CO} \rightarrow \text{Fe}_2\text{O}_3 + \text{CO}_2 \uparrow + \text{SO}_2 \uparrow$ and $\text{CaSO}_4 + \text{CO} \rightarrow \text{CaO} + \text{CO}_2 \uparrow + \text{SO}_2 \uparrow$), melting and slagging ($\text{FeO} + \text{SiO}_2 \rightarrow 2\text{FeO} \cdot \text{SiO}_2$ and $\text{Fe}_2\text{O}_3 + \text{CaO} \rightarrow \text{CaO} \cdot \text{Fe}_2\text{O}_3$) under the action of combustion heat at 1500°C to 1550°C , to obtain high temperature slag at about 1500°C and flue gas containing SO_2 . Therefore, the weak reducing atmosphere is used for desulfurization and melting, which is conducive to achieve the decomposition of gypsum and solve the problems that it is difficult to adapt to the composition fluctuation of the lateritic nickel ore leaching tailings due to the narrow mixing range of the reducing agent (too much or too little reducing agent is not conducive to desulfurization) and the problem of bond caused by too high temperature of reduction and desulfurization during conventional reduction and desulfurization. Specifically, the first fuel spray lance can adopt coal, gas, pulverized coal, fuel oil, natural gas and other fuels. The combustion-supporting air used may include oxygen-enriched air having a concentration of oxygen not less than 65 vol% and an excess air coefficient ranging from 0.95 to 0.98. The slag type can be $\text{FeO}-\text{Fe}_3\text{O}_4-\text{CaO}-\text{SiO}_2-\text{MgO}-\text{Al}_2\text{O}_3$, which has very good fluidity at the melting temperature of the mixed material.

[0060] According to the embodiments of the present disclosure, in order to improve the subsequent reduction efficiency, an appropriate amount of reducing agent can also be added to the above mixed material for preliminary reduction, and the specific chemical reaction equations include: $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe}_3\text{O}_4 + \text{CO}_2 \uparrow$ and $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow \text{FeO} + \text{CO}_2 \uparrow$.

[0061] According to the embodiments of the present disclosure, secondary air can be blown into the flue gas containing SO_2 for secondary combustion, and the CO in the flue gas containing SO_2 is burned off. Specifically, the O_2 content in the flue gas containing SO_2 after secondary combustion can be controlled to be between 2 vol% and 4 vol%. The inventors have found that if the content of O_2 is too low, secondary combustion is incomplete; if the content of O_2 is too high, the amount of the flue gas will be increased, and the proportion of SO_2 converted into SO_3 will be increased. By controlling the content of O_2 in the flue gas containing SO_2 after secondary combustion within the above rang, the present disclosure can not only make the secondary combustion reaction complete, but also can reduce the flue gas and the proportion of SO_2 converted into SO_3 .

[0062] According to the embodiments of the present disclosure, the flue gas containing SO₂ above can be firstly cooled to below 1200°C by recovering waste heat by a flue gas waste heat boiler to generate steam, then cooled to about 200°C by a flue gas heat exchanger to generate hot air of 700°C to 800°C, and finally sent for acid production after dust collection treatment, thereby realizing the comprehensive utilization of sulfur element in the lateritic nickel ore leaching tailings. The steam generated by recovering the waste heat from the flue gas waste heat boiler can be used to pre-dry the tailings after filter pressing in the lateritic nickel ore wet leaching system. The hot air of 700°C-800°C obtained after heat exchange by the flue gas heat exchanger can be used as a heat source for preheating the mixed material, and the insufficient part can be supplemented by burning the coal gas, pulverized coal, fuel oil or other fuels. Thus, the heat utilization rate of the whole process can be increased and the energy consumption can be reduced.

[0063] According to the embodiments of the present disclosure, prior to melting and slagging desulfurization, the mixed material obtained by mixing the lateritic nickel ore leaching tailings with the flux can be dried and crushed. Therefore, the particle size of the mixed material can be decreased, the specific surface area of the mixed material is increased, free water in the mixed material is removed, and partial gypsum in the lateritic nickel ore leaching tailings is dehydrated into semi-hydrated gypsum and CaSO₄ (H₂O → H₂O ↑ , CaSO₄·2H₂O→CaSO₄·0.5H₂O+H₂O↑ 120°C-150°C, and CaSO₄·0.5H₂O→CaSO₄+H₂O↑≥165°C), thereby increasing the efficiency of subsequent melting and slagging desulfurization and reducing energy consumption of the chemical material. Meanwhile, the mixed material can be homogenized, which is beneficial to the reduction and iron extraction. Specifically, the water content of the lateritic nickel ore leaching tailings after drying and crushing can be not greater than 2 wt%, the particle size can be not greater than 2 mm, the flux particle size can be not greater than 2 mm, and the heat source of drying and crushing can be coal gas, pulverized coal, fuel oil or other fuels. Moreover, a crusher, a pneumatic powder lifting device and a dust collecting device can be used for drying and crushing. A ball mill, a vertical mill, an air swept mill and a hammer crusher with both crushing and drying functions can be used as the crusher; the pneumatic powder lifting device can be a pneumatic lifting pump; and the dust collecting device can be a bag dust collector. The hot air

temperature at an inlet of the crusher can be 600°C to 800°C. The tail gas temperature of the bag can be 120°C to 150°C; the air-charge ratio is $\geq 200 \text{ Nm}^3/\text{t}$ (the specific amount required is obtained by the thermal equilibrium calculation according to the water content of the wet material and the hot air temperature); and the airflow velocity of the pneumatic air lifting device is 4 m/s to 10 m/s (if the air flow velocity is too low, the particle size of the dried slag is too fine, and the dust rate is too high when melting; if the air flow velocity is too high, on the one hand, the particle size of the dry slag is too coarse and the pipeline wear is large, and on the other hand, the system resistance is large and the energy consumption is high). The retention time of the material in the pneumatic powder lifting device is $\geq 2\text{s}$, and the coal gas can be used as the heat source of the crusher. When the coal gas is insufficient, other fuels such as pulverized coal and fuel oil can also be used.

[0064] According to the embodiments of the present disclosure, prior to performing the melting and slagging desulfurization of the mixed material, the above mixed material can also be preheated in advance, so that they can be rapidly preheated and decomposed, and the temperature can be appropriately raised. Specific chemical reaction equations include:
 $\text{H}_2\text{O} \rightarrow \text{H}_2\text{O}\uparrow$, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O}\uparrow$, $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O}\uparrow$,
 $\text{Fe}(\text{OH})_3 \rightarrow \text{Fe}_2\text{O}_3 + \text{H}_2\text{O}\uparrow$, $\text{Al}(\text{OH})_3 \rightarrow \text{Al}_2\text{O}_3 + \text{H}_2\text{O}\uparrow$, $\text{Ca}(\text{OH})_2 \rightarrow \text{CaO} + \text{H}_2\text{O}\uparrow$, and
 $\text{CaMgC}_2\text{O}_6 \rightarrow \text{CaCO}_3 + \text{MgO} + \text{H}_2\text{O}\uparrow$. Thus, it can improve the efficiency of subsequent melting and slagging desulfurization and reduce the energy consumption of the chemical material.

[0065] Specifically, 3-5 stage cyclone preheater and an electric dust collector can be used for the preheating. The preheating mode can be countercurrent heat exchange. The hot air of 700°C to 800°C generated in the waste heat recovery process in the subsequent step of the melting and slagging desulfurization can be used as the preheating heat source, and the insufficient part can be supplemented by burning coal gas, pulverized coal, fuel oil and other fuels. The temperature of the hot air at the inlet of the cyclone preheater ranges from 700°C to 800°C; the temperature of the mixed material after preheating can be 500°C to 650°C; and the temperature of the tail gas after preheating is $\leq 200^\circ\text{C}$. The tail gas is evacuated after dust removal by the electric dust collector, and the collected dust is returned to the cyclone preheater. The tail gas after dust removal can be used as a heat source for pre-drying to reduce the energy consumption of pre-drying. Moreover, the inventors have found that if the temperature of the

hot air used for preheating is too high, part of the sulfate (decomposition temperature of aluminum sulfate is 685°C) will decompose in advance, which is not conducive to the subsequent recovery and utilization of SO₂; and if the temperature of the hot air used for preheating is too low, the temperature of the mixed material will be too low, which is not conducive to improving the efficiency of subsequent melting and slagging desulfurization and reducing the energy consumption of the chemical material. By controlling the temperature of the hot air used for preheating within the above range, the present disclosure can not only improve the efficiency of subsequent melting and slagging desulfurization and reduce the energy consumption of the chemical material, but also can avoid the decomposition of sulfate in advance, which is conducive to the subsequent recovery and utilization of SO₂. In addition, high temperature tail gas can be produced after preheating the mixed materials with hot air , and the tail gas can be used to pre-dry the tailings after filter pressing in the lateritic nickel ore wet leaching system, which can realize the full utilization of waste heat, thereby reducing the energy consumption.

[0066] S300: mixing the slag with a reducing agent for reduction and iron extraction.

[0067] In this step, the slag is mixed with the reducing agent for reduction and iron extraction to obtain molten iron, iron extraction slag and coal gas. Specifically, the end of the reducing agent spray lance and the end of the second fuel spray lance extend below a slag layer, and the oxygen-enriched air and the fuel enter below the slag layer by the second fuel spray lance for submerged combustion to provide heat for reduction and iron extraction. The specific chemical reaction equations include $C_aH_bO_cN_dSe+O_2\rightarrow CO+H_2O+N_2+SO_2$, and $CO+O_2\rightarrow CO_2\uparrow$. The reducing agent enter below the slag layer by the reducing agent spray lance, and is mixed with the slag and reduced for iron extraction at 1400°C-1500°C. Under the action of the reducing agent, the iron oxide in the slag is reduced to metallic iron to obtain molten iron, iron extraction slag and coal gas. The specific chemical reaction equations include: $Fe_3O_4+CO\rightarrow FeO+CO_2\uparrow$, $FeO+C\rightarrow Fe+CO\uparrow$ and $CaO+SiO_2\rightarrow 2CaO\cdot SiO_2$. The molten iron will settle at the bottom of the furnace due to high density, so it will be separated from the iron extraction slag. The discharge temperature of the molten iron can be 1400°C to 1500°C, and the discharge temperature of the iron extraction slag can be 1450°C to 1550°C. The iron content of the iron extraction slag is $\leq 5\%$, and the molten iron can be used for steelmaking, so as to

realize the comprehensive utilization of iron element in the lateritic nickel ore leaching tailings. The iron extraction slag can be used as building materials after being subjected to water fragmentation. In addition, because more heat is required for melting and slagging desulfurization, and less heat is required for reduction and iron extraction, it can reduce the energy consumption and decrease production and operation cost by separating melting and slagging desulfurization from reduction and iron extraction.

[0068] Specifically, a reduction and iron extraction furnace can be used for the reduction and iron extraction. The anthracite or coke fines can be used as reducing agent, the particle size of which can be 2 mm to 5 mm, and the fixed carbon content is $\geq 70\%$. The amount of the reducing agent for producing each ton of molten iron is not less than 300 kg. Meanwhile, in the process of reduction and iron extraction, the carburizing agent can be sprayed into the molten iron layer, thereby improving the carburizing efficiency. The anthracite or coke fines can be used as the carburizing agent, and a $\text{CaO-SiO}_2\text{-MgO-Al}_2\text{O}_3$ slag system can be used for reduction and iron extraction. By adding the flux in the preheating process, the mass ratio of CaO to SiO_2 in the iron extraction slag can be controlled to be (0.9-1.2): 1; the content of MgO in the iron extraction slag can be controlled to range from 6 wt% to 10 wt%; the viscosity of the iron extraction slag at 1450°C is less than $0.8\text{Pa}\cdot\text{s}$, having very good fluidity.

[0069] According to the embodiments of the present disclosure, the end of the second fuel spray lance may be located below 200 mm on the upper surface of the slag layer and above the surface of the molten iron. For the second fuel spray lance, high calorific value fuels such as pulverized coal, natural gas, and fuel oil can be used. The combustion-supporting air used may include oxygen-enriched air having a concentration of oxygen not less than 65 vol%. In addition, the inventors have found that by controlling the excess air coefficient, the volume of CO in the reaction system accounts for not less than 80% of the total volume of CO and CO_2 , which is conducive to improving the reduction effect and reducing the iron content of the iron extraction slag.

[0070] According to the embodiments of the present disclosure, heat can be supplemented by a third fuel spray lance and/or an electrode in the process of reduction and iron extraction. When the heat is supplemented by the third fuel spray lance, the end of the third fuel spray lance extends below the slag layer, and the oxygen-enriched air and the fuel enter below the

slag layer by the third fuel spray lance for submerged combustion to supplement the heat for reduction and iron extraction. When the heat is supplemented by the electrode, the end of the electrode extends below the slag layer to supplement the heat for reduction and iron extraction. Specifically, for the third fuel spray lance, high calorific value fuels such as pulverized coal, natural gas, and fuel oil can be used. The combustion-supporting air used may include oxygen-enriched air having a concentration of oxygen not less than 65 vol%. In addition, the inventors have found that by controlling the excess air coefficient, the volume of CO in the reaction system accounts for not less than 80% of the total volume of CO and CO₂, which can improve the reduction effect and reduce the iron content of the iron extraction slag.

[0071] According to the embodiments of the present disclosure, the coal gas obtained from the reduction and iron extraction is collected under negative pressure, and the clean coal gas can be obtained after waste heat recovery, cooling and dust removal. Most of the clean coal gas is used as fuel for melting and slagging desulfurization, and the rest is used as a heat source for preheating, drying and crushing. The steam generated from waste heat recovery can be used to pre-dry the tailings after filter pressing in the lateritic nickel ore wet leaching system, which can improve the utilization efficiency of the coal gas (compared with conventional gas power generation) and the heat utilization rate of the entire process, thereby reducing the energy consumption. Moreover, the coal gas utilization device can be used for the waste heat recovery, cooling and dust removal of the coal gas. The coal gas utilization device can use a coal gas waste heat boiler, a cooling dust collecting device, a pressurization fan, a coal gas storage tank and a torch. After the coal gas comes out of the reduction and iron extraction furnace, the coal gas is cooled to about 850°C to 1000°C through the flue duct of the coal gas waste heat boiler, and then quenched to below 200°C by the cooling dust collecting device. The quenched coal gas is pressurized by the fan, then fed into the coal gas storage tank, and can be used as fuel for the steps of pre-drying, pre-heating, desulfurizing and melting.

[0072] Thus, the method for resource utilization of lateritic nickel ore leaching tailings in the present disclosure can solve the problem of the environmental protection hazards in the lateritic nickel ore leaching tailings, comprehensively utilize the valuable elements therein such as iron and sulfur, and produce considerable economic benefits, and is low in energy consumption, low in production cost, easy to operate, suitable for large-scale production and

high in practical value. Moreover, by separately performing the operations of pre-drying, drying and crushing, preheating, melting and slagging desulfurization, and reduction and iron extraction, the advantages of the various stages are fully utilized; the steam produced by waste heat recovery in melting and slagging desulfurization and reduction and iron extraction or the tail gas in the preheating process is pre-dried; and the coal gas produced in the reduction and iron extraction is subjected to drying and crushing, preheating and melting and slagging desulfurization, thereby achieving high-efficiency utilization of the coal gas (compared with the conventional coal gas power generation). It should be noted that, the method can also be used to produce nickel iron from the lateritic nickel ore, thereby replacing a rotary kiln electric furnace (RKEF) technology.

[0073] In the second aspect of the present disclosure, the present disclosure provides a system for resource utilization of lateritic nickel ore leaching tailings. According to the embodiments of the present disclosure, referring to Fig. 2, the system includes: a mixing device 100, a melting and slagging desulfurization device 200 and a reducing device 300.

[0074] According to the embodiments of the present disclosure, referring to Fig. 2, the mixing device 100 has an inlet 101 for lateritic nickel ore leaching tailings, a flux inlet 102, and a mixed material outlet 103, and is adapted to mix the lateritic nickel ore leaching tailings with a flux to obtain a mixed material. Specifically, the water content of the lateritic nickel ore leaching tailings ranges from 15 wt% to 20 wt%, which is neither dusty nor clumped, and is conducive to the subsequent distribution and transportation. Based on the dry basis of the lateritic nickel ore leaching tailings, the content of calcium element in the lateritic nickel ore leaching tailings is not greater than 8 wt%, and the content of iron element ranges from 25 wt% to 50 wt% and the content of sulfur element ranges from 3 wt% to 10 wt%. The flux comprises CaO and MgO. When the system works, the lateritic nickel ore leaching tailings are fed into the mixing device 100 via the inlet 101 for lateritic nickel ore leaching tailings. At the same time, the flux is fed into the mixing device 100 through the flux inlet 102, the lateritic nickel ore leaching tailings and the flux are mixed in the mixing device 100 to obtain the mixed material. The mixed material is discharged through the mixed material outlet 103. By mixing the lateritic nickel ore leaching tailings with the flux before the melting and slagging desulfurization, the internal structure and the chemical compositions of the slag obtained later can be adjusted to

improve the metallurgical properties of the slag and reduce the temperature of reduction and iron extraction, which is conducive to the process of reduction and iron extraction. The lateritic nickel ore leaching tailings and the flux are mixed at a ratio enabling a mass ratio of CaO to SiO₂ in the iron extraction slag obtained by reduction and iron extraction to be (0.9-1.2): 1, and the content of MgO in the iron extraction slag to be 6wt% to 10 wt%.

[0075] According to the embodiments of the present disclosure, referring to Figs. 3-4, the melting and slagging desulfurization device 200 has a mixed material inlet 201, a slag outlet 202 and a flue gas outlet 203, the mixed material inlet 201 is connected with the mixed material outlet 103, and the melting and slagging desulfurization device is adapted to perform a melting and slagging desulfurization on the mixed material to obtain slag and flue gas containing SO₂. Specifically, the melting and slagging desulfurization device 200 can include a melting and slagging desulfurization device body 204, a mixed material spray lance 205, a first fuel spray lance 206, a secondary tuyere 207 and a flue duct 208. The melting and slagging desulfurization device body 204 includes a furnace 2041 and a slag region 2042 from top to bottom. The mixed material spray lance 205 is provided with the mixed material inlet 201; the end of the mixed material spray lance 205 and the end of the first fuel spray lance 206 extend into the slag region 2042; the secondary tuyere 207 is arranged on the furnace 2041; the flue duct 208 is communicated with the furnace 2041; the flue duct 208 is provided with the flue gas outlet 203; and the slag outlet 202 is arranged on a side wall of the slag region 2042. The oxygen-enriched air and the fuel enter below the slag by the first fuel spray lance 206 for submerged combustion to provide heat for the melting of the mixed material. The specific chemical reaction equations include $\text{CaH}_2\text{O}_6\text{NdS}_e + \text{O}_2 \rightarrow \text{CO} + \text{H}_2\text{O} + \text{N}_2 + \text{SO}_2$, and $\text{CO} + \text{O}_2 \rightarrow \text{CO}_2 \uparrow$. The mixed material enters below the slag by the mixed material spray lance 205, and undergo the reactions of decomposition ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \uparrow$), desulfurization ($\text{Al}_2(\text{SO}_4)_3 + \text{CO} \rightarrow \text{Al}_2\text{O}_3 + \text{CO}_2 \uparrow + \text{SO}_2 \uparrow$, $\text{Fe}_2(\text{SO}_4)_3 + \text{CO} \rightarrow \text{Fe}_2\text{O}_3 + \text{CO}_2 \uparrow + \text{SO}_2 \uparrow$ and $\text{CaSO}_4 + \text{CO} \rightarrow \text{CaO} + \text{CO}_2 \uparrow + \text{SO}_2 \uparrow$), melting and slagging ($\text{FeO} + \text{SiO}_2 \rightarrow 2\text{FeO} \cdot \text{SiO}_2$ and $\text{Fe}_2\text{O}_3 + \text{CaO} \rightarrow \text{CaO} \cdot \text{Fe}_2\text{O}_3$) under the action of combustion heat at 1500°C to 1550°C to obtain high temperature slag at about 1500°C and flue gas containing SO₂. Therefore, the reduction, desulfurization and melting and slagging can be performed separately. The weak reducing atmosphere is used for desulfurization and melting, which is conducive to achieve the decomposition of gypsum and solve the problem that it is

difficult to adapt to the composition fluctuation of the lateritic nickel ore leaching tailings due to the narrow mixing range of the reducing agent (too much or too little reducing agent is not conducive to desulfurization) and the problem of bond caused by too high temperature of reduction and desulfurization during conventional reduction and desulfurization. The obtained high temperature slag is discharged through the slag outlet 202, and the flue gas containing SO₂ enters the furnace 2041. The secondary air is blown into the furnace 2041 via the secondary tuyere 207 to make the flue gas containing SO₂ undergo secondary combustion and discharge through the flue gas outlet 203 to ensure that the O₂ content in the flue gas containing SO₂ discharged through the flue gas outlet 203 is between 2 vol% and 4 vol%, which can make the CO in the flue gas containing SO₂ burn off and reduce the proportion of the flue gas and SO₂ converted into SO₃.

[0076] According to the embodiments of the present disclosure, a top of the slag region 2042 is spaced apart from a bottom of the melting and slagging desulfurization device body 204 by a distance not less than 800 mm to avoid damaging the furnace bottom when the slag is stirred to improve the reaction efficiency. The end of the mixed material spray lance 205 is spaced apart from the top of the slag region 2042 by a distance not less than 200 mm. The end of the first fuel spray lance 206 is spaced apart from the top of the slag region 2042 by a distance less than 200 mm. The mixed material is pneumatically conveyed to 200 mm below the top of the slag region 2042 in the melting and slagging desulfurization device body 204 by the mixed material spray lance 205. The oxygen-enriched air and the fuel are injected to 200 mm below the top of the slag region 2042 by the first fuel spray lance 206 for submerged combustion to provide heat for melting of the mixed material to improve the melting efficiency. For the first fuel spray lance 206, high calorific value fuels such as pulverized coal, natural gas, and fuel oil can be used. The combustion-supporting air used may include oxygen-enriched air having a concentration of oxygen not less than 65 vol%. The excess air coefficient may be 0.95 to 0.98, and the flux slag type can be FeO-Fe₃O₄-CaO-SiO₂-MgO-Al₂O₃, which has very good fluidity at the melting temperature of the mixed material.

[0077] According to the embodiments of the present disclosure, in order to improve the reduction efficiency, an appropriate amount of the reducing agent can also be added into the above mixed material. Specific chemical reaction equations include: $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe}_3\text{O}_4 + \text{CO}_2 \uparrow$,

and $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow \text{FeO} + \text{CO}_2 \uparrow$.

[0078] According to the embodiments of the present disclosure, the melting and slagging desulfurization device body 204 can be a melt pool smelting furnace. The melt pool smelting furnace can include a furnace bottom 2043, a furnace wall 2044 and a furnace top 2045. The furnace wall 2044 is arranged around the furnace bottom 2043; the furnace top 2045 covers the furnace wall 2044; the furnace bottom 2043 can be an adiabatic structure; the furnace wall 2044 can be of a water jacket embedded refractory brick structure; both the slag outlet 202 and the secondary tuyere 207 are arranged on the furnace wall 2044; and the slag outlet 202 can be a suction mouth. The end of the mixed material spray lance 205 and the end of the first fuel spray lance 206 can extend into the melt pool smelting furnace through the furnace wall 2044, and when the slag is stirred, the mixed material spray lance 205 and the first fuel spray lance 206 can be lifted. Meanwhile, when the melt pool smelting furnace is used for oxygen-enriched melt pool smelting, the low-priced lignite can be utilized, thereby reducing the cost. It can be understood that, referring to Fig. 5, the end of the mixed material spray lance 205 can also extend into the melt pool smelting furnace by the furnace top 2045.

[0079] According to the embodiments of the present disclosure, referring to Fig. 6, the melting and slagging desulfurization device 200 further includes a flue gas waste heat recovery device 21 and an electric dust collector (not shown) connected to each other, wherein the flue gas waste heat recovery device 21 is connected with the flue gas outlet 203 on the flue duct 208. Specifically, the flue gas waste heat recovery device 21 can include a flue gas waste heat boiler (not shown) and a flue gas heat exchanger (not shown) connected to each other. The flue gas containing SO_2 discharged from the flue gas outlet 203 can be firstly cooled to 1200°C or below by a flue gas waste heat boiler to generate steam, then cooled to about 200°C by a flue gas heat exchanger to generate hot air of 700 to 800°C , and finally sent for acid production after the dust is collected by the electric dust collector, thereby realizing comprehensive utilization of the sulfur element in the lateritic nickel ore leaching tailings. The steam generated by recovering the waste heat from the flue gas waste heat boiler can be used to pre-dry the tailings after filter pressing in the lateritic nickel ore wet leaching system. The hot air of 700 - 800°C obtained after heat exchange by the flue gas heat exchanger can be used as a heat source for preheating the mixed material, and the insufficient part can be supplemented by burning the coal gas,

pulverized coal, fuel oil or other fuels, thereby increasing the heat utilization rate of the whole process and reducing the energy consumption.

[0080] According to the embodiments of the present disclosure, referring to Figs. 7-8, the reducing device 300 includes a slag inlet 301, a reducing agent inlet 302, a molten iron outlet 303, an iron extraction slag outlet 304 and a coal gas outlet 305, wherein the slag inlet 301 is connected with the slag outlet 202. The reducing device is adapted to mix the slag with the reducing agent and perform the reduction and iron extraction to obtain the molten iron, iron extraction slag and coal gas. Specifically, the reducing device 300 can include a reducing device body 306, a reducing agent spray lance 307, a second fuel spray lance 308, a carburizing agent spray lance 309 and a heat supplementing device 310. The reducing device body 306 is provided with a reducing region 3061, a carburizing region 3062 and a settling region 3063 along a horizontal direction, wherein a partition wall 3064 is arranged between the carburizing region 3062 and the settling region 3063. A bottom end of the partition wall 3064 is spaced apart from a bottom of the reducing device body 306 by a distance. The slag inlet 301, the reducing agent spray lance 307 and the second fuel spray lance 308 are all arranged in the reducing region 3061, and the end of the reducing agent spray lance 307 and the end of the second fuel spray lance 308 extend below the slag layer 3066 of the reducing region 3061. The reducing agent spray lance 307 is provided with a reducing agent inlet 302. The carburizing agent spray lance 309 is arranged in the carburizing region 3062, and the end of the carburizing agent spray lance 309 extend below the slag layer 3066 of the reducing region 3062. The heat supplementing device 310 is arranged in the carburizing region 3062 and the settling region 3063. The molten iron outlet 303 is arranged in the molten iron layer 3065 of the settling region 3063; the iron extraction slag outlet 304 is arranged in the slag layer 3066 of the settling region 3063; and the slag inlet 301 can be connected with the slag outlet 202 through a launder (not shown). High-temperature slag at about 1500°C is continuously added into the reducing region 3061 of the reducing device body 306 through the launder, and the oxygen-enriched air and the fuel enter below the slag layer 3066 of the reducing region 3061 by the second fuel spray lance 308 for submerged combustion. Specific chemical reaction equations include $C_aH_bO_cN_dS_e+O_2\rightarrow CO+H_2O+N_2+SO_2$, and $CO+O_2\rightarrow CO_2\uparrow$. The reducing agent is sprayed below the slag layer 3066 of the reducing region 3061 by the reducing agent spray lance 307,

mixed with the high-temperature slag and subjected to reduction and iron extraction at 1400°C to 1500°C. In the presence of the reducing agent, iron oxides in the slag are reduced into metallic iron to obtain the molten iron, iron extraction slag and coal gas, and the specific chemical reaction equations include $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow \text{FeO} + \text{CO}_2\uparrow$, $\text{FeO} + \text{C} \rightarrow \text{Fe} + \text{CO}\uparrow$, and $\text{CaO} + \text{SiO}_2 \rightarrow 2\text{CaO} \cdot \text{SiO}_2$. The obtained molten iron and iron extraction slag flow into the carburizing region 3062. The molten iron will gradually settle at the bottom of the furnace due to relatively high density, so it will be separated from the iron extraction slag so as to form the molten iron layer 3065 and the slag layer 3066. The airflow ejected from the carburizing agent spray lance 309 can blow the carburizing agent into the molten iron layer 3065 to increase the carburizing efficiency. The molten iron and partial iron extraction slag in the carburizing region 3062 can pass under the partition wall 3064 and flow into the settling region 3063, and the partition wall 3064 can decrease the fluctuation of the settling region 3063, which is conducive to improve the separation effect of the molten iron from the iron extraction slag. In the reduction and iron extraction process, heat can be supplemented by the heat supplementing device 310. The molten iron in the settling region 3063 is discharged from the molten iron outlet 303 and can be used for steelmaking, thereby realizing comprehensive utilization of the iron element in the lateritic nickel ore leaching tailings. The iron extraction slag is discharged from the iron extraction slag outlet 304 and may be used as a raw building material after being subjected to water fragmentation. The obtained coal gas is discharged from the coal gas outlet 305. Moreover, because of more heat is required for melting and slagging desulfurization and less heat is required for reduction and iron extraction, it can reduce the energy consumption and decrease production and operation cost by performing the operations of melting and slagging desulfurization and reduction and iron extraction in different apparatuses, respectively.

[0081] According to the embodiments of the present disclosure, for reduction and iron extraction, the $\text{CaO-SiO}_2\text{-MgO-Al}_2\text{O}_3$ slag system can be used. By adding the flux in the preheating process, the mass ratio of CaO to SiO_2 in the iron extraction slag is controlled to be (0.9-1.2):1, and content of MgO in the iron extraction slag is controlled to range from 6 wt% to 10 wt%, and the viscosity of the iron extraction slag is less than 0.8 Pa·s at 1450°C, having very good fluidity. Specifically, the retention time of the iron extraction slag in the settling region 3043 is ≥ 30 min to reduce the iron content; the discharge temperature of the molten iron can be

1400°C to 1500°C; and the discharge temperature of the iron extraction slag can be 1450°C to 1550°C.

[0082] According to the embodiments of the present disclosure, the reducing device body 306 can be a melt pool smelting furnace; the furnace bottom is an adiabatic structure; the furnace wall at a position of the molten iron layer 3065 is of a refractory material structure; the slag layer 3066 and the furnace wall above the slag layer 3066 are of a water jacket embedded refractory brick structure; and the partition wall 3064 can be a water-cooled wall. Moreover, the reducing device body 306 can be maintained at a slight positive pressure, thereby avoiding a condition that purity of the coal gas is decreased due to excessive air leakage.

[0083] According to the embodiments of the present disclosure, the end of the second fuel spray lance 308 is spaced apart from the top of the slag layer 3066 by a distance not less than 200 mm, and the second fuel spray lance is located above the molten iron layer; for the second fuel spray lance, high calorific value fuels such as pulverized coal, natural gas, and fuel oil can be used; the combustion-supporting air used may include oxygen-enriched air with the concentration of oxygen not less than 65 vol%; and an excess air coefficient is controlled so that the volume of CO in the reaction system accounts for not less than 80% of the total volume of CO and CO₂, thereby increasing a reduction effect and reducing the iron content of the iron extraction slag. The reducing agent can be anthracite or coke fines, the particle size of which can be 2 mm to 5 mm and the fixed carbon content is $\geq 70\%$, and the amount of the reducing agent for producing each ton of the molten iron is not less than 300 kg. For the carburizing agent, anthracite or coke fines can be used.

[0084] According to the embodiments of the present disclosure, a heat supplementing device 310 may include a third fuel spray lance and/or an electrode. When the heat is supplemented by the third fuel spray lance, the end of the third fuel spray lance extend below the slag layer 3066, and the oxygen-enriched air and the fuel enter below the slag layer 3066 by the third fuel spray lance for submerged combustion to provide heat for the reduction and iron extraction; and when the heat is supplemented by the electrode, the end of the electrode extend below the slag layer 3066 to provide heat for the reduction and iron extraction. Specifically, for the third fuel spray lance, high calorific value fuels such as pulverized coal, natural gas, and fuel oil can be used; the combustion-supporting air used may include oxygen-

enriched air having the concentration of oxygen not less than 65 vol%; and in addition, the inventors have found that, the excess air coefficient is controlled so that the volume of CO in the reaction system accounts for not less than 80% of the total volume of CO and CO₂, which can improve the reduction effect and reduce the iron content of the iron extraction slag.

5 **[0085]** According to the embodiments of the present disclosure, referring to Fig. 9, the system further includes a pre-drying treatment device 400 and a first dust collecting device (not shown). The pre-drying treatment device 400 is provided with a lateritic nickel ore leaching tailings inlet 401, a dried leaching tailing outlet 402 and a pre-dried tail gas outlet 403, wherein the dried leaching tailing outlet 402 is connected with the lateritic nickel ore leaching tailings
10 inlet 401, and the pre-dried tail gas outlet 403 is connected with the first dust collecting device. Moreover, the pre-drying treatment device is adapted to perform the pre-drying treatment on the lateritic nickel ore leaching tailings in advance before the lateritic nickel ore leaching tailings are mixed with the flux. Specifically, the water content of the tailings after filter pressing in the lateritic nickel ore wet leaching system ranges from 30 wt% to 45 wt%; and the tailings
15 are fed into the pre-drying treatment device 400 via the lateritic nickel ore leaching tailings inlet 401, so that part of the water in the tailings after filter pressing in the lateritic nickel ore wet leaching system can be removed to obtain the lateritic nickel ore leaching tailings with water content of 15 wt% to 20 wt%. The lateritic nickel ore leaching tailings with water content of 15 wt% to 20 wt% are neither dusty nor clumped, which is conducive to the subsequent distribution
20 and transportation. The tail gas produced in the pre-drying treatment enters the first dust collecting device via the pre-dried tail gas outlet 403 for evacuation after dust removal.

[0086] According to the embodiments of the present disclosure, for the pre-drying treatment device 400, a steam drier or a rotary drying kiln can be used. When the steam drier is used, the pre-drying treatment device 400 can be connected with a flue gas waste heat recovery device
25 21, a heat exchange mode is indirect heat exchange, a heat source can be the steam generated in the process of waste heat recovery of the flue gas that is obtained by the melting and slagging desulfurization device 200, and the temperature is $\geq 120^{\circ}\text{C}$; and when the rotary drying kiln is used, a direct heat exchange is conducted, a concurrent drying kiln is preferred, the hot air temperature is $\leq 700^{\circ}\text{C}$, the tail gas temperature ranges from 105 to 120°C , and the first dust
30 collecting device can be a bag dust collector.

[0087] According to the embodiments of the present disclosure, referring to Fig. 10, the above system further includes a drying and crushing device 500. The drying and crushing device 500 is provided with an inlet 501 for a material to be treated and an outlet 502 for a dried and crushed material, wherein the inlet 501 for the material to be treated is connected with a mixed material outlet 103, and the outlet 502 for the dried and crushed material is connected with a mixed material inlet 201. Moreover, the drying and crushing device 500 is adapted to dry and crush the mixed material in advance before the mixed material is supplied to the melting and slagging desulfurization device 200, and supply the obtained dried and crushed mixed material to the melting and slagging desulfurization device 200. Specifically, the drying and crushing device 500 may include a drying and crushing device body (not shown), a powder pneumatic lifting device (not shown) and a second dust collecting device (not shown) which are connected in sequence. The drying and crushing device body is provided with the inlet 501 for a material to be treated; the second dust collecting device is provided with the outlet 502 for a dried and crushed material; the mixed material enters the drying and crushing device body via the inlet 501 for material to be treated, is crushed under the action of a mechanical force, and is rapidly uniformly mixed and dried by hot air. The dried and crushed mixed material is fed into the second dust collecting device by the powder pneumatic lifting device to be collected to obtain the dried and crushed mixed material; and the mixed material collected in the second dust collecting device is dried and crushed and then fed to the melting and slagging desulfurization device 200 via the outlet 502 for the dried and crushed material. Therefore, the particle size of the mixed material can be decreased, a specific surface area of the mixed material is increased, free water in the mixed material is removed, and partial gypsum in the lateritic nickel ore leaching tailings is dehydrated into semi-hydrated gypsum and CaSO_4 ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 0.5\text{H}_2\text{O} + \text{H}_2\text{O}\uparrow$, and $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O}\uparrow$), thereby increasing the efficiency of subsequent melting and slagging desulfurization and reducing energy consumption of the chemical material. Meanwhile, the mixed material can be homogenized, which is beneficial to the reduction and iron extraction.

[0088] Specifically, the hot air used by the drying and crushing device can be at a temperature of 600°C to 800°C; the tail gas temperature of the second dust collecting device can be 120°C to 150°C; an air-charge ratio is more than and equal to 200 Nm^3/t (the specific

amount is obtained by the thermal equilibrium calculation according to the water content of the mixed material and the hot air temperature); and an airflow velocity of the powder pneumatic lifting device can be 4 m/s to 10 m/s, thereby avoiding a too high dust rate due to a too low particle size of the dried slag or large pipeline wear, high system resistance and high energy consumption caused by a too high particle size of the dried slag. The retention time of the material in the pneumatic lifting device is not less than 2s, and the water content of the dried and crushed mixed material is not more than 2 wt% and the particle size is not more than 2 mm.

[0089] It should be noted that, the specific types of the drying and crushing device body, the powder pneumatic lifting device and the second dust collecting device can be selected by those skilled in the art according to actual needs. For example, the drying and crushing device body may be a ball mill, a vertical mill, an air swept mill or a hammer crusher and any other apparatus with both crushing and drying functions; the powder pneumatic lifting device can be a pneumatic lifting pump; and the second dust collecting device can be a bag dust collector.

[0090] According to the embodiments of the present disclosure, referring to Fig. 11, the system further includes a preheating device 600 and a third dust collecting device 61. The preheating device 600 is provided with a mixed material inlet 601, a preheated material outlet 602, and a preheated tail gas outlet 603, wherein the mixed material inlet 601 is connected with the mixed material outlet 103, and the preheated material outlet 602 is connected with the mixed material inlet 201. The preheating device is adapted to: preheat the mixed material in advance before the mixed material is supplied to the melting and slagging desulfurization device 200, and supply the obtained preheated mixed material to the melting and slagging desulfurization device 200. The third dust collecting device 61 is provided with a preheated tail gas inlet 611, a dust collecting outlet 612 and an outlet for tail gas outlet after dust collection 613, wherein the preheated tail gas inlet 611 is connected with the preheated tail gas outlet 603, the dust collecting outlet 612 is connected with the mixed material inlet 601, and the outlet for tail gas outlet after dust collection 613 is connected with the pre-drying treatment device 400. Specifically, the mixed material is fed into the preheating device 600 via the mixed material inlet 601, so that it can be rapidly preheated and decomposed, and the temperature is appropriately raised to obtain the preheated mixed material and preheated tail gas. Specific

chemical reaction equations include: $\text{CaSO}_4 \cdot 2\text{H}_2\text{O} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O} \uparrow$,

$\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O}\uparrow$, $\text{Fe}(\text{OH})_3 \rightarrow \text{Fe}_2\text{O}_3 + \text{H}_2\text{O}\uparrow$, $\text{Al}(\text{OH})_3 \rightarrow \text{Al}_2\text{O}_3 + \text{H}_2\text{O}\uparrow$,
 $\text{Ca}(\text{OH})_2 \rightarrow \text{CaO} + \text{H}_2\text{O}\uparrow$, and $\text{CaMgC}_2\text{O}_6 \rightarrow \text{CaCO}_3 + \text{MgO} + \text{H}_2\text{O}\uparrow$. The obtained preheated mixed

material is fed to the melting and slagging desulfurization device 200 via the preheated material outlet 602, thereby increasing the efficiency of subsequent melting and slagging desulfurization and reducing energy consumption of the chemical material. The obtained preheated tail gas enters the third dust collecting device 61 via the preheated tail gas inlet 611 for dust removal to obtain the dust-collected tail gas and flue after dust collection, and the obtained tail gas after dust collection is fed into the pre-drying treatment device 400 via the outlet for tail gas after dust collection 613 to serve as a heat source of the pre-drying treatment device, which can realize full utilization of the waste heat, thereby reducing the energy consumption. The obtained smoke dust returns to the preheating device 600 via the dust collecting outlet 612, thereby increasing a resource utilization rate of the lateritic nickel ore leaching tailings. According to one specific embodiment of the present disclosure, referring to Fig. 12, the mixed material inlet 601 can be connected with the outlet for the dried and crushed material 502, and thus the dried and crushed mixed material is further preheated, thereby increasing the efficiency of subsequent melting and slagging desulfurization and reducing the energy consumption of the chemical material.

[0091] According to the embodiments of the present disclosure, the third dust collecting device 61 can be an electric dust collector; the preheating device 600 can be a cyclone preheater; a preheating mode can be countercurrent heat exchange; an heat source used can be the hot air of 700-800°C generated in the waste heat recovery process by the flue gas containing SO₂ that is obtained by melting and slagging desulfurization; the temperature of the obtained preheated tail gas is ≤200°C; and the temperature of the preheated mixed material can be 500°C to 650°C. It should be noted that, the stages of the cyclone preheater can be selected by those skilled in the art according to actual needs, for example, 3 to 5 stages.

[0092] According to the embodiments of the present disclosure, referring to Fig. 13, the system further includes a coal gas utilization device 31. The coal gas utilization device 31 is connected with the coal gas outlet 305, the pre-drying treatment device 400, the preheating device 600 and the melting and slagging desulfurization device 200, and is adapted to collect and supply the coal gas generated in the reducing device, as fuel, to at least one of the pre-

drying treatment device 400, the preheating device 600 and the melting and slagging desulfurization device 200. Specifically, the coal gas utilization device 31 can include a coal gas waste heat boiler (not shown), a cooling dust collecting device (not shown), a pressurization fan (not shown) and a coal gas storage tank (not shown) which are connected in sequence. The coal gas discharged out of the coal gas outlet 305 is collected under a negative pressure, cooled to about 850°C to 1000°C through the coal gas waste heat boiler, and then quenched to below 200°C by the cooling dust collecting device to obtain clean coal gas. The quenched coal gas is pressurized by the fan, then fed into the coal gas storage tank, and can be used as fuel for the pre-drying treatment device 400, the preheating device 600 and the melting and slagging desulfurization device 200. The steam generated by the coal gas waste heat boiler can be used to pre-dry the tailings after filter pressing in the lateritic nickel ore wet leaching system. Thus, the coal gas utilization efficiency (compared with conventional coal gas power generation) and the heat utilization rate of the whole process can be increased, thereby reducing the energy consumption.

[0093] It should be noted that, the soot generated by the system can also be mixed with the lateritic nickel ore leaching tailings and the flux for the melting and slagging desulfurization and conduct reduction and iron extraction, thereby further increasing the resource utilization rate of the lateritic nickel ore leaching tailings.

[0094] Therefore, the system for resource utilization of lateritic nickel ore leaching tailings disclosed by the present disclosure not only can solve the problem of environmental protection hazards of the lateritic nickel ore leaching tailings, but also can comprehensively utilize valuable elements therein such as iron and sulfur and produce considerable economic benefits, and is low in energy consumption and low in production cost. Moreover, by performing the operations of pre-drying, drying and crushing, preheating, melting and slagging desulfurization, and reduction and iron extraction in different apparatuses, respectively; the advantages of the various stages are fully utilized; the steam generated by waste heat recovery in the operations of melting and slagging desulfurization and reduction and iron extraction or the tail gas in the preheating process is used for pre-drying; and the coal gas generated in the reduction and iron extraction is used for drying and crushing, preheating and melting and slagging desulfurization, thereby achieving high-efficiency utilization of the coal gas (compared with the conventional

coal gas power generation). It should be noted that, the system can also be used to produce nickel iron from the lateritic nickel ore, thereby replacing a rotary kiln electric furnace (RKEF) technology.

[0095] The present disclosure is described below with reference to the specific examples.

5 It should be noted that, these examples are merely descriptive, rather than limiting the present disclosure in any way.

[0096] Example 1

[0097] 20 t of tailings after filter pressing in the lateritic nickel ore wet leaching system (the water content in wet basis was 35 wt%, the components of the dry basis were: 5.1 wt% of Ca, 10 32.5 wt% of Fe, 7.2 wt% of S, 6.0 wt% of Si and 2.5 wt% of Al) were dried by a steam drier until the water content was 18% to obtain 15.85 t of lateritic nickel ore leaching tailings, and 4.55 t of saturated steam at 180°C was consumed. The lateritic nickel ore leaching tailings was neither dusty or clumped.

[0098] 200 kg/h of the lateritic nickel ore leaching tailings, 5.1 kg/h of limestone powder, 15 32.8 kg/h of dolomite powder and 4.9 kg/h of soot were added into the drying and crushing device, and 166 Nm³/h of hot air at 700°C was introduced for drying for 2.5 s to obtain 208.3 kg/h of dried tailings with water content of 1.8% (that is, the dried and crushed mixed material).

[0099] The 208.3 kg/h of dried tailings were added into the preheating device for preheating, and 153.3 Nm³/h of heat exchange hot air at 750°C generated by the melting and slagging 20 desulfurization device, 6.6 kg/h of pulverized coal and 143.8 Nm³/h of combustion-supporting air were introduced to obtain 194.6 kg/h of hot calcine at 600°C (that is, the preheated mixed material).

[00100] The 194.6 kg/h of hot calcine, 36.8 Nm³/h of oxygen-enriched air (containing 70 vol% of O₂) and 114.2 Nm³/h of coal gas were sprayed into a position 200 mm below the melt 25 pool surface (that is, the top of a slag melting region) in the melting and slagging desulfurization device; the excess air coefficient was controlled to be 0.97; a melting temperature was controlled to be 1500°C; a depth of the melt pool (that is, the distance between the top of the slag melting region and the bottom of the melting and slagging desulfurization device body) was controlled to be 900 mm. The hot calcine underwent the reactions of decomposition, 30 desulfurization, melting and slagging under the action of combustion heat; and 143.6 kg/h of

high-temperature slag was produced, including the following components in mass fraction: 34.4% of TFe, 16.3% of CaO, 15.8% of SiO₂, 6.9% of Al₂O₃, 5.2% of MgO and 0.1% of S and has excellent fluidity. In addition, 39.2 Nm³/h of secondary air was blown into a furnace wall to obtain 178.6 Nm³/h of high-temperature flue gas at 1450°C (containing 3.0 vol% of O₂ and 4.1 vol% of SO₂), and the flue gas was cooled to about 1150°C by the flue gas waste heat boiler and cooled to about 180°C by utilizing a flue gas heat exchanger, and then fed to an acid making system to obtain 153.3 Nm³/h of hot air at about 750°C (which is used for preheating the dried tailings).

[00101] The 143.6 kg/h of high-temperature slag was added into a reducing region of the reducing device body via a launder. In addition, 16.2 kg/h of anthracite was added by a reducing agent spray lance, and 38.2 kg/h of bituminous coal and 54.4 Nm³/h of combustion-supporting air (containing 70 vol% of O₂) were blown in by the second fuel spray lance. The high-temperature slag that flowed into the reducing device body reacted with the added reducing agent at 1400°C to 1450°C, wherein iron oxides were reduced into metallic iron and carburized.

The slag iron settled and was separated in the settling region; the settling time was ≥ 30 min; the power consumption in the settling region was 11.2 kW; a discharge temperature of the molten iron was about 1450°C; a discharge temperature of the iron extraction slag was about 1500°C; and both the molten iron and the iron extraction slag had excellent fluidity. 47.9 kg/h of molten iron (grade of 94.6%, containing 0.2% of S and 4.0% of C) and 86.9 kg/h of iron extraction slag (the content of Fe was 5.5 wt%, a mass ratio of CaO to SiO₂ was 1.0, the content of MgO was 8.4 wt%, the content of Al₂O₃ was 12.8 wt%, and the viscosity at 1450°C was less than 0.8 Pa·s) were obtained.

[00102] The coal gas obtained by the reducing device was cooled to about 850°C by the coal gas waste heat boiler, quenched to about 180°C, and then used for preheating after dust removal and pressurization to obtain 122.1 Nm³/h of coal gas (51.2 vol% of CO and 9.6 vol% of H₂).

[00103] The recovery rate of sulfur was 97.8%, the comprehensive recovery rate of Fe was 92.3%, and the coal consumption per ton of iron was 1.3 kg/t (including 337 kg/t of anthracite and 935 kg/h of bituminous coal) during the process for treating the lateritic nickel ore leaching tailings.

[00104] Example 2

[00105] 200 kg/h of the dried lateritic nickel ore leaching tailings in example 1 and 39.5 kg/h of dolomite powder were added into the drying and crushing device, and 205.1 Nm³/h of hot air at 600°C was introduced for drying for 2.5 s to obtain 210 kg/h of dried tailings with water content of 1.5% (that is, the dried and crushed mixed material).

5 **[00106]** The 210 kg/h of dried tailings were added into the preheating device for preheating, and 217.9 Nm³/h of heat exchange hot air at 700°C generated by the melting and slagging desulfurization device, 3.3 kg/h of pulverized coal and 94.4 Nm³/h of combustion-supporting air were introduced to obtain 195.6 kg/h of hot calcine at 500°C (that is, the preheated mixed material).

10 **[00107]** The 195.6 kg/h of hot calcine, 56.8 Nm³/h of oxygen-enriched air (containing 65 vol% of O₂), 10 kg/h of bituminous coal and 112.4 Nm³/h of coal gas were sprayed into a position 200 mm below the melt pool surface (that is, the top of a slag melting region) in the melting and slagging desulfurization device; the excess air coefficient was controlled to be 0.95; a melting temperature was controlled to be 1500°C; a depth of the melt pool (that is, the distance
15 between the top of the slag melting region and the bottom of the melting and slagging desulfurization device body) was controlled to be 800 mm. The hot calcine underwent the reactions of decomposition, desulfurization, melting and slagging under the action of combustion heat; and 144.8 kg/h of high-temperature slag was produced, including the following components in mass fraction: 34.2% of TFe, 15.9% of CaO, 15.8% of SiO₂, 7% of
20 Al₂O₃, 6% of MgO and 0.1% of S and had excellent fluidity. In addition, 71.9 Nm³/h of secondary air was blown into a furnace wall to obtain 236.2 Nm³/h of high-temperature flue gas at 1445°C (containing 4.0 vol% of O₂ and 3.1 vol% of SO₂), and the flue gas was cooled to about 1150°C by the flue gas waste heat boiler and cooled to about 180°C by utilizing a flue gas heat exchanger, and then fed to an acid making system to obtain 217.9 Nm³/h of hot air at
25 about 700°C (which is used for preheating the dried tailings).

[00108] The 144.8 kg/h of high-temperature slag was added into a reducing region of the reducing device body via a launder. In addition, 16.3 kg/h of anthracite was added by a reducing agent spray lance, and 32.4 kg/h of bituminous coal and 52.4 Nm³/h of combustion-supporting air (containing 65 vol% of O₂) were blown in by the second fuel spray lance. The high-
30 temperature slag that flowed into the reducing device body reacted with the added reducing

agent at 1400-1450°C, wherein iron oxides were reduced into metallic iron and carburized. The slag iron was settled and separated in the settling region; the settling time was ≥ 30 min; the power consumption in the settling region was 14.1 kW; a discharge temperature of the molten iron was about 1480°C; a discharge temperature of the iron extraction slag was about 1550°C; and both the molten iron and the iron extraction slag had excellent fluidity. 47.6 kg/h of molten iron (grade of 94.2%, containing 0.1% of S and 4.5% of C) and 88.3 kg/h of iron extraction slag (the content of Fe was 6.0 wt%, a mass ratio of CaO to SiO₂ was 0.9, the content of MgO was 9.8 wt%, the content of Al₂O₃ was 12.7 wt%, and the viscosity at 1450°C was less than 0.8 Pa·s) were obtained.

[00109] The coal gas obtained by the reducing device was cooled to about 850°C by the coal gas waste heat boiler, then was quenched to about 180°C, and used for preheating and immersion melting after dust removal and pressurization to obtain 112.4 Nm³/h of coal gas (47.2 vol% of CO and 8.2 vol% of H₂).

[00110] The recovery rate of sulfur was 98.1%, the comprehensive recovery rate of Fe was 91.2%, and the coal consumption per ton of iron was 1.3 kg/t (including 343 kg/t of anthracite and 959 kg/h of bituminous coal during the process for treating the lateritic nickel ore leaching tailings).

[00111] Example 3

[00112] 200 kg/h of the dried lateritic nickel ore leaching tailings in example 1, 22.5 kg/h of limestone powder and 25.3 kg/h of dolomite powder were added into the drying and crushing device, and 141.1 Nm³/h of hot air at 800°C was introduced for drying for 2.5 s to obtain 218 kg/h of dried tailings with water content of 1.95% (that is, the dried and crushed mixed material).

[00113] The 218 kg/h of dried tailings were added into the preheating device for preheating, and 102.6 Nm³/h of heat exchange hot air at 800°C generated by the melting and slagging desulfurization device, 30.7 Nm³/h of coal gas and 149.8 Nm³/h of combustion-supporting air were introduced to obtain 204.2 kg/h of hot calcine at 650°C (that is, the preheated mixed material).

[00114] The 204.2 kg/h of hot calcine, 27.5 Nm³/h of oxygen-enriched air (containing 80 vol% of O₂) and 86.7 Nm³/h of coal gas were sprayed into a position 200 mm below the melt pool surface (that is, the top of a slag melting region) in the melting and slagging desulfurization

device; the excess air coefficient was controlled to be 0.98; a melting temperature was controlled to be 1500°C; a depth of the melt pool (that is, the distance between the top of the slag melting region and the bottom of the melting and slagging desulfurization device body) was controlled to be 1000 mm; the hot calcine underwent the reactions of decomposition, desulfurization, melting and slagging under the action of combustion heat; and 149.4 kg/h of high-temperature slag was produced, including the following components in mass fraction: 33.1% of TFe, 19.8% of CaO, 15.4% of SiO₂, 6.5% of Al₂O₃, 3.9% of MgO and 0.1% of S and had excellent fluidity. In addition, 19.4 Nm³/h of secondary air was blown into a furnace wall to obtain 129 Nm³/h of high-temperature flue gas at 1475°C (containing 2.0 vol% of O₂ and 5.6 vol% of SO₂), and the flue gas was cooled to about 1150°C by the flue gas waste heat boiler and cooled to about 180°C by utilizing a flue gas heat exchanger, and then fed to an acid making system to obtain 102.6 Nm³/h of hot air at about 800°C (which is used for preheating the dried tailings).

[00115] The 149.4 kg/h of high-temperature slag was added into a reducing region of the reducing device body via a launder. In addition, 16.1 kg/h of anthracite was added by a reducing agent spray lance, and 44.2 kg/h of bituminous coal and 52.4 Nm³/h of combustion-supporting air (containing 80 vol% of O₂) were blown in by the second fuel spray lance. The high-temperature slag that flowed into the reducing device body reacted with the added reducing agent at 1400°C to 1450°C, wherein iron oxides were reduced into metallic iron and carburized.

The slag iron was settled and separated in the settling region; the settling time was ≥30 min; the power consumption in the settling region was 8.5 kW; a discharge temperature of the molten iron was about 1410°C; a discharge temperature of the iron extraction slag was about 1450°C; and both the molten iron and the iron extraction slag had excellent fluidity. 48.1 kg/h of molten iron (grade of 94.9%, containing 0.2% of S and 3.7% of C) and 92.8 kg/h of iron extraction slag (the content of Fe was 5.0 wt%, a mass ratio CaO to SiO₂ was 1.2, the content of MgO was 6.3 wt%, the content of Al₂O₃ was 11.9 wt%, and the viscosity at 1450°C was less than 0.8 Pa·s) were obtained.

[00116] The coal gas obtained by the reducing device was cooled to about 850°C by the coal gas waste heat boiler, quenched to about 180°C, and then used for preheating and immersion melting after dust removal and pressurization to obtain 128.2 Nm³/h of coal gas (56.7 vol% of

CO and 11.3 vol% of H₂).

[00117] The recovery rate of sulfur was 97.4%, the comprehensive recovery rate of Fe was 92.9%, and the coal consumption per ton of iron was 1.3 kg/t (including 335 kg/t of anthracite and 920 kg/h of bituminous coal) during the process for treating the lateritic nickel ore leaching
5 tailings

[00118] It can be seen from examples 1 to 3 that, the method for resource utilization of lateritic nickel ore leaching tailings disclosed by the present disclosure not only can solve the problem of environmental protection hazards of the lateritic nickel ore leaching tailings, but also can comprehensively utilize valuable elements therein such as iron and sulfur to produce
10 considerable economic benefits, and is low in energy consumption, low in production cost, simple in process, easy to operate, suitable for mass production and extremely high in practical value.

[00119] In the description of this specification, the description referring to the terms “one embodiment”, “some embodiments”, “example”, “specific example” or “some examples”, etc.
15 means that specific features, structures, materials or characteristics described in combination with the embodiment or example are included in at least one embodiment or example of the present disclosure. In this description, the schematic expressions for the above terms are not necessarily aimed at the same embodiment or example. Moreover, the described specific features, structures, materials or characteristics can be combined appropriately in any one or
20 more embodiments or examples. In addition, those skilled in the art can combine and integrate different embodiments or examples and features of different embodiments or examples described in this description without contradicting each other.

[00120] Although the embodiments of the present disclosure have been shown and described above, it will be appreciated that the above embodiments are exemplary and shall not be
25 understood as limitations to the present disclosure. Those ordinary skilled in the art can make changes, modifications, replacements and variations to the above embodiments within the scope of the present disclosure.

CLAIMS

What is claimed is:

1. A method for resource utilization of lateritic nickel ore leaching tailings, comprising:

(1) mixing the lateritic nickel ore leaching tailings with a flux to obtain a mixed material;

5 (2) performing a melting and slagging desulfurization on the mixed material to obtain slag and flue gas containing SO_2 ; and

(3) mixing the slag with a reducing agent for reduction and iron extraction to obtain molten iron, iron extraction slag, and coal gas.

10 2. The method according to claim 1, wherein the lateritic nickel ore leaching tailings are pre-dried prior to said mixing the lateritic nickel ore leaching tailings with the flux.

3. The method according to claim 1 or 2, wherein in step (1), drying and crushing are performed subsequent to said mixing the lateritic nickel ore leaching tailings with the flux.

4. The method according to any one of claims 1 to 3, wherein in step (1), the flux comprises CaO and MgO .

15 5. The method according to any one of claims 1 to 4, wherein the lateritic nickel ore leaching tailings and the flux are mixed at a ratio enabling a mass ratio of CaO to SiO_2 in the iron extraction slag to be (0.9-1.2): 1 and a content of MgO in the iron extraction slag to be 6 wt% to 10 wt%.

20 6. The method according to any one of claims 1 to 5, wherein in step (2), a temperature of the melting and slagging desulfurization ranges from 1500°C to 1550°C .

7. The method according to any one of claims 1 to 6, wherein ends of a first fuel spray lance and a mixed material spray lance extend below the slag during the melting and slagging desulfurization.

25 8. The method according to any one of claims 1 to 7, wherein combustion-supporting air adopted by the first fuel spray lance comprises oxygen-enriched air, a concentration of oxygen in the oxygen-enriched air being not less than 65 vol%, and an excess air coefficient ranging from 0.95 to 0.98.

9. The method according to any one of claims 1 to 8, wherein in step (3), a temperature of

reduction and iron extraction ranges from 1400°C to 1500°C.

10. The method according to any one of claims 1 to 9, wherein an end of a second fuel spray lance extends below a slag layer during the reduction and iron extraction.

11. The method according to any one of claims 1 to 10, wherein the reduction and iron
5 extraction is supplemented with heat by a third fuel spray lance and/or an electrode.

12. The method according to any one of claims 1 to 11, wherein when the reduction and iron extraction is supplemented with heat by a third fuel spray lance, the end of the third fuel spray lance extends below a slag layer, and a volume of CO in a reaction system accounts for not less than 80% of a total volume of CO and CO₂.

10 13. The method according to any one of claims 1 to 12, wherein the mixed material is preheated prior to said performing the melting and slagging desulfurization on the mixed material.

14. The method according to any one of claims 1 to 13, wherein a temperature of a preheated mixed material ranges from 500°C to 650°C.

15. A system for resource utilization of lateritic nickel ore leaching tailings, comprising:
15 a mixing device having an inlet for the lateritic nickel ore leaching tailings, a flux inlet, and, a mixed material outlet, the mixing device being adapted to mix the lateritic nickel ore leaching tailings with a flux to obtain a mixed material;

a melting and slagging desulfurization device having a mixed material inlet, a slag outlet and a flue gas outlet, the mixed material inlet being connected with the mixed material outlet,
20 and the melting and slagging desulfurization device being adapted to perform a melting and slagging desulfurization on the mixed material to obtain slag and flue gas containing SO₂; and

a reducing device having a slag inlet, a reducing agent inlet, a molten iron outlet, an iron extraction slag outlet, and a coal gas outlet, the slag inlet being connected with the slag outlet, and the reducing device being adapted to mix the slag with a reducing agent for reduction and
25 iron extraction to obtain molten iron, iron extraction slag, and coal gas.

16. The system according to claim 15, further comprising a pre-drying treatment device, wherein:

the pre-drying treatment device has a lateritic nickel ore leaching tailings inlet and a dried leaching tailings outlet connected with the lateritic nickel ore leaching tailings inlet; and

30 the pre-drying treatment device is adapted to pre-dry the lateritic nickel ore leaching

tailings before the lateritic nickel ore leaching tailings are mixed with the flux.

17. The system according to claim 15 or 16, further comprising a drying and crushing device, wherein:

the drying and crushing device has an inlet for a material to be treated and an outlet for a
5 dried and crushed material, the inlet for the material to be treated being connected with the mixed material outlet, and the outlet for the dried and crushed material being connected with the mixed material inlet; and

the drying and crushing device is adapted to dry and crush the mixed material before the mixed material is supplied to the melting and slagging desulfurization device; and supply the
10 dried and crushed mixed material to the melting and slagging desulfurization device.

18. The system according to any one of claims 15 to 17, further comprising:

a preheating device having a mixed material inlet, a preheated material outlet, and a preheated tail gas outlet, the mixed material inlet being connected with the mixed material outlet, the preheated material outlet being connected with the mixed material inlet, and the preheating
15 device being adapted to: preheat the mixed material before the mixed material is supplied to the melting and slagging desulfurization device; and supply the preheated mixed material to the melting and slagging desulfurization device; and

a dust collecting device having a preheated tail gas inlet, a dust collecting outlet, and an outlet for tail gas after dust collection, the preheated tail gas inlet being connected with the
20 preheated tail gas outlet, the dust collecting outlet being connected with the mixed material inlet, and the outlet for the tail gas after dust collection being connected with the pre-drying treatment device.

19. The system according to any one of claims 15 to 18, wherein the melting and slagging desulfurization device comprises:

25 a melting and slagging desulfurization device body comprising a furnace and a slag region from top to bottom;

a mixed material spray lance having an end extending into the slag region;

a first fuel spray lance having an end extending into the slag region;

a secondary tuyere arranged on the furnace;

30 a flue duct in communication with the furnace; and

a slag outlet arranged on a side wall of the slag region.

20. The system according to any one of claims 15 to 19, wherein the melting and slagging desulfurization device further comprises a flue gas waste heat recovery device connected with the flue duct.

5 21. The system according to any one of claims 15 to 20, wherein the reducing device comprises:

10 a reducing device body having, along a horizontal direction, a reducing region, a carburizing region, and a settling region, a partition wall being arranged between the carburizing region and the settling region, and a bottom end of the partition wall being spaced apart from a bottom of the reducing device body by a distance;

 a slag inlet arranged in the reducing region;

 a reducing agent arranged in the reducing region;

 a second fuel spray lance arranged in the reducing region and having an end extending below the slag layer of the reducing region;

15 a carburizing agent spray lance arranged in the carburizing region and having an end extending into the slag layer of the carburizing region; and

 a heat supplementing device arranged in the carburizing region and the settling region.

22. The system according to any one of claims 15 to 21, further comprising a coal gas utilization device, wherein:

20 the coal gas utilization device is connected with the coal gas outlet, the pre-drying treatment device, the preheating device, and the melting and slagging desulfurization device; and

25 the coal gas utilization device is adapted to collect and supply the coal gas generated in the reducing device, as fuel, to at least one of the pre-drying treatment device, the preheating device and the melting and slagging desulfurization device.

23. The system according to any one of claims 15 to 22, wherein:

 a top of the slag region is spaced apart from a bottom of the melting and slagging desulfurization device body by a distance not less than 800 mm;

30 an end of the mixed material spray lance is spaced apart from the top of the slag region by a distance not less than 200 mm, and

an end of the first fuel spray lance is spaced apart from the top of the slag region by a distance not less than 200 mm.

24. The system according to any one of claims 15 to 23, wherein an end of the second fuel spray lance is spaced apart from the top of the slag layer by a distance not less than 200 mm

5 and is located above a molten iron layer.

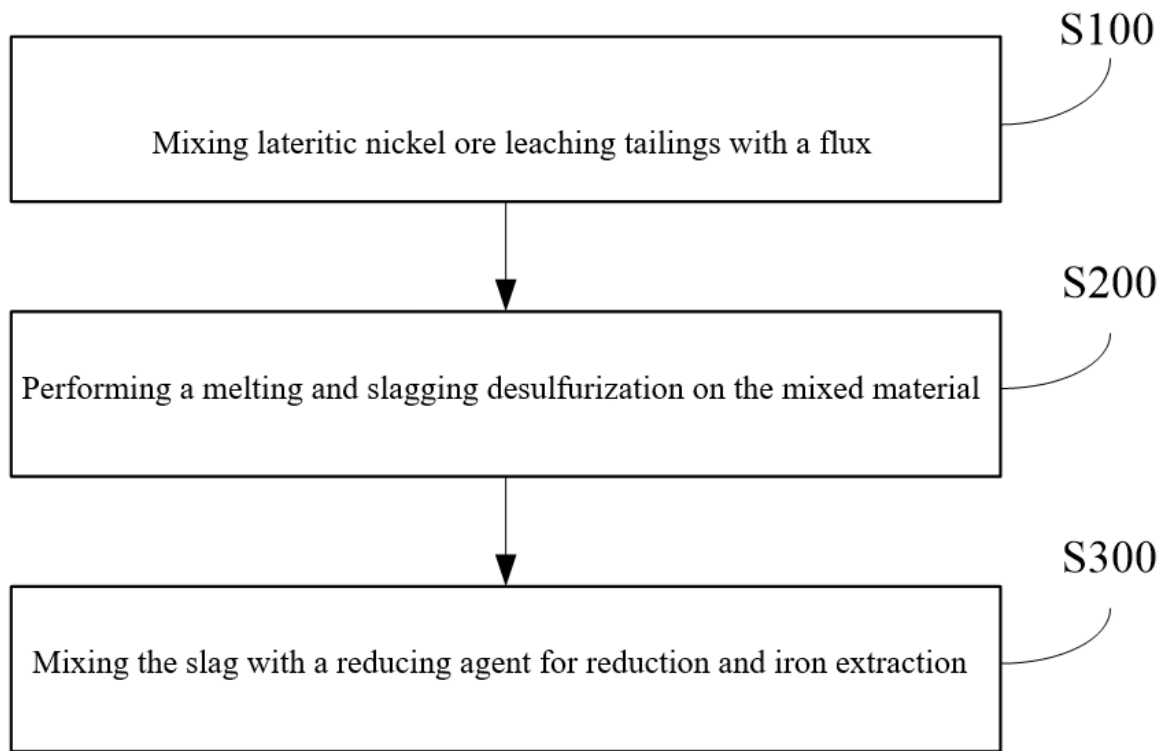


Fig. 1

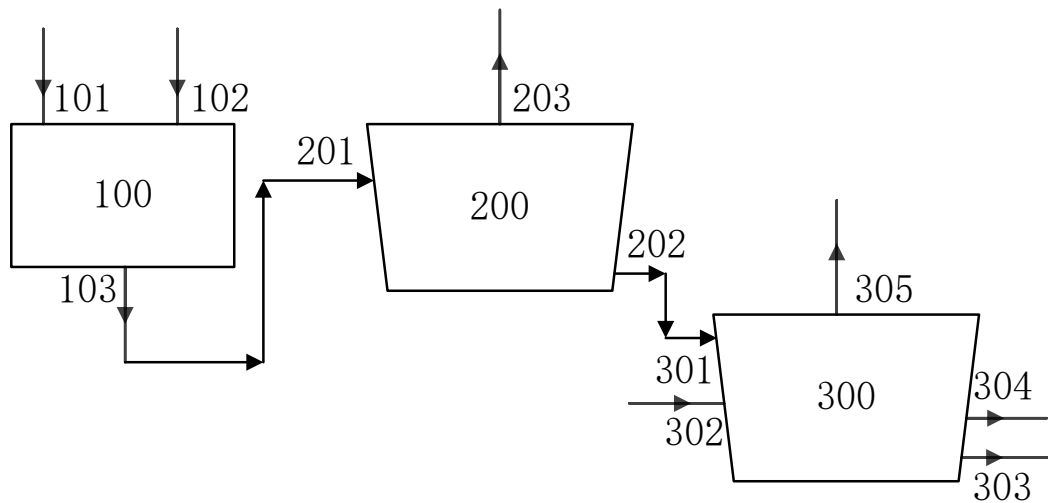


Fig. 2

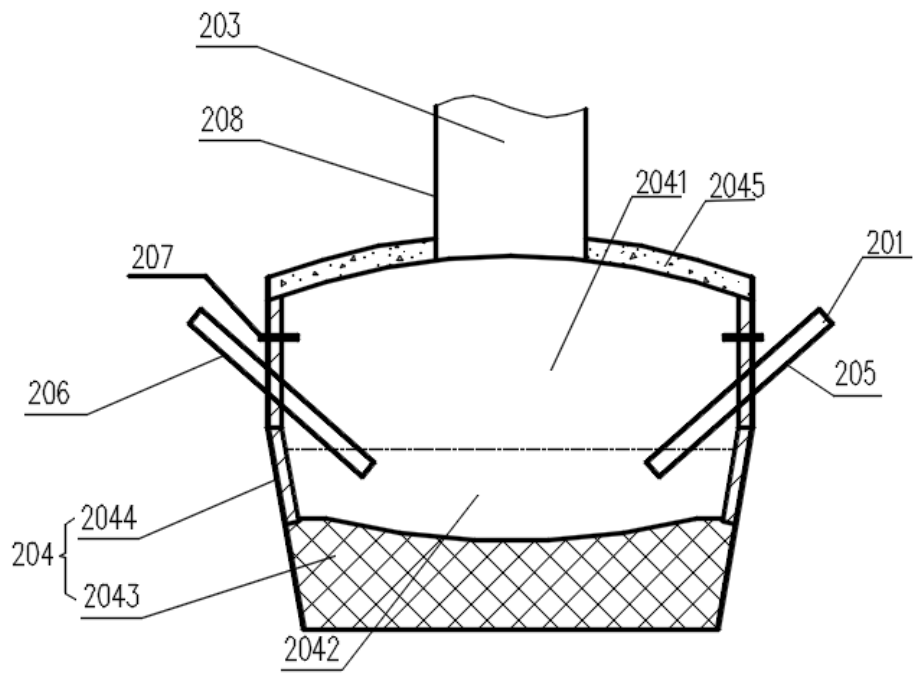


Fig. 3

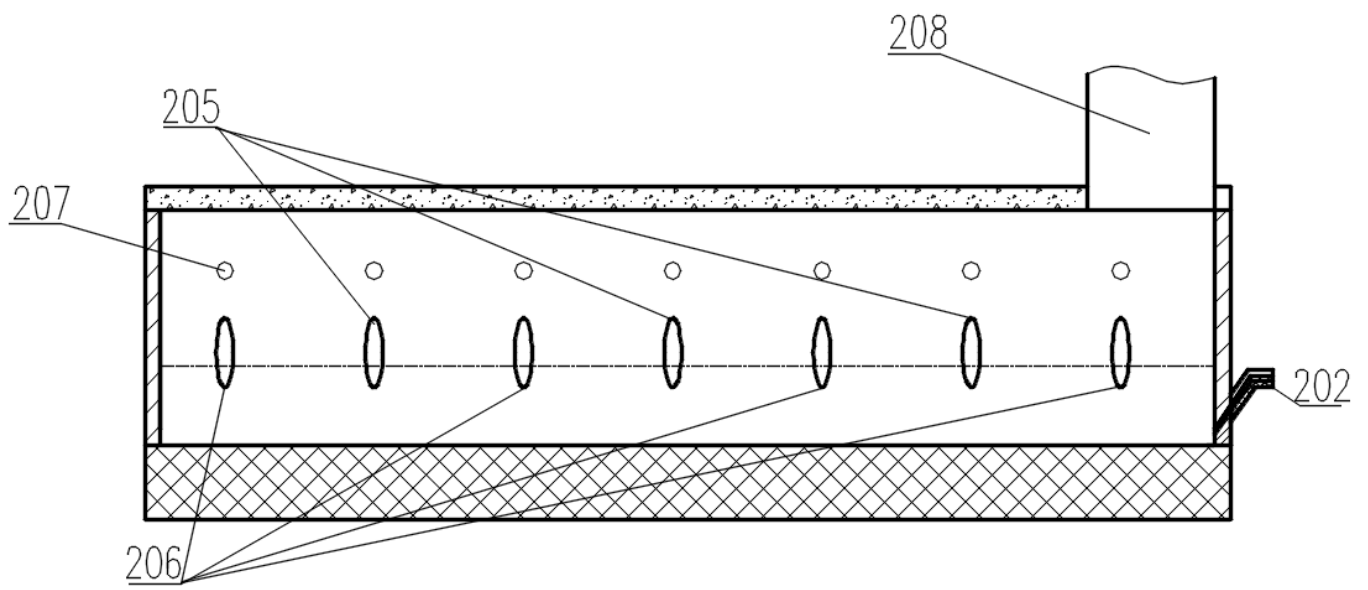


Fig. 4

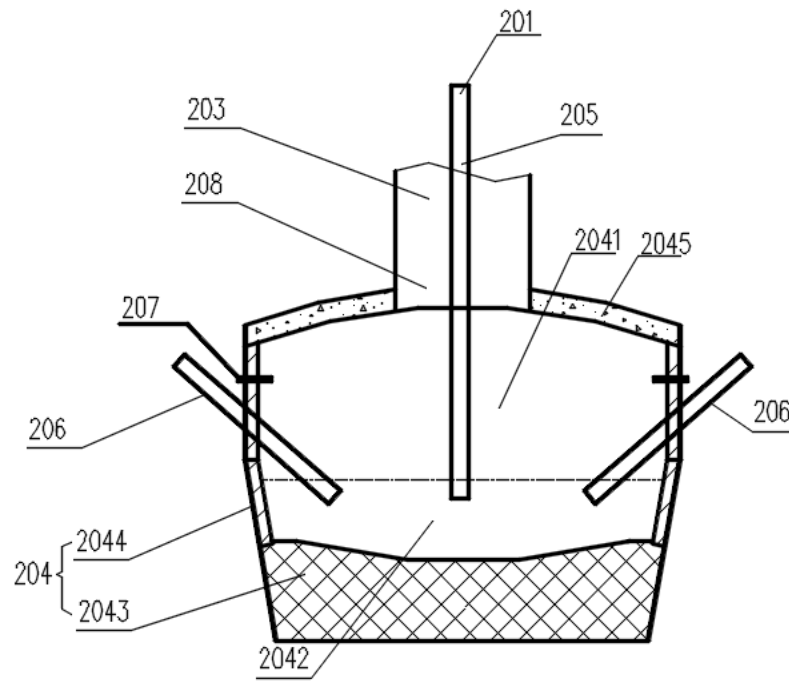


Fig. 5

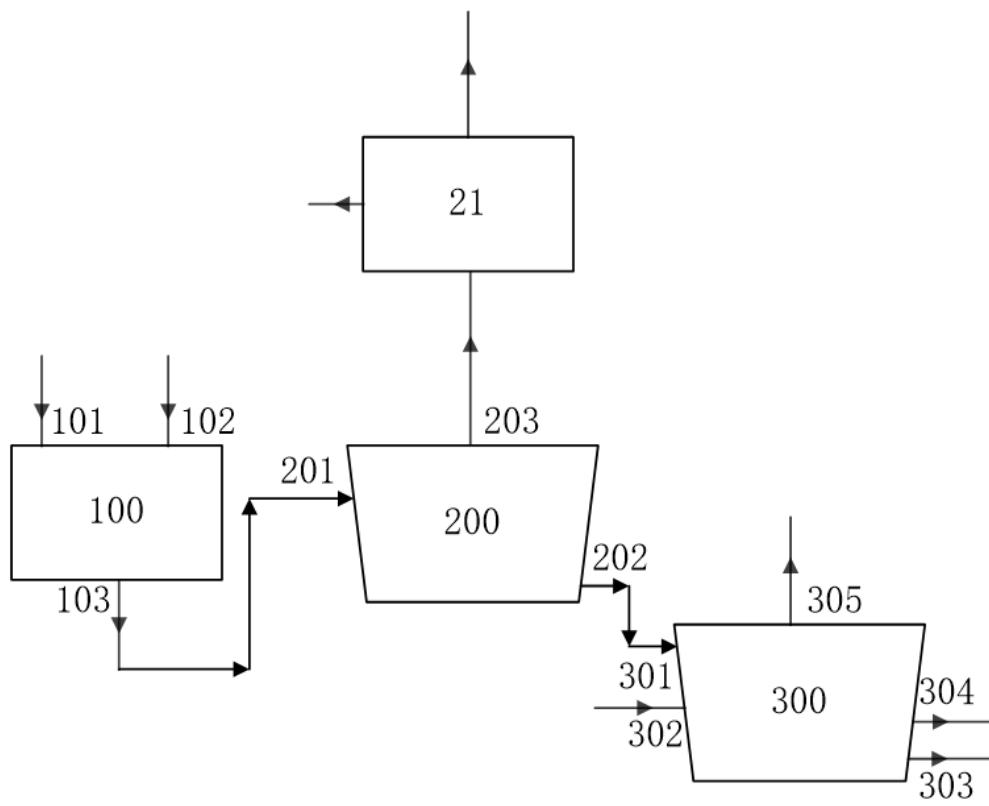


Fig. 6

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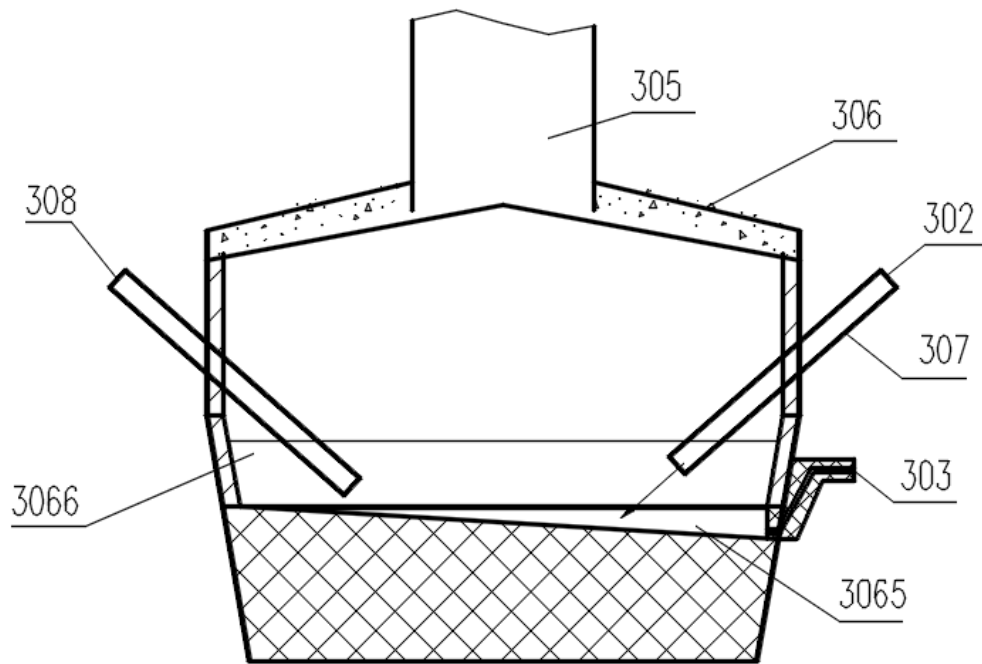


Fig. 7

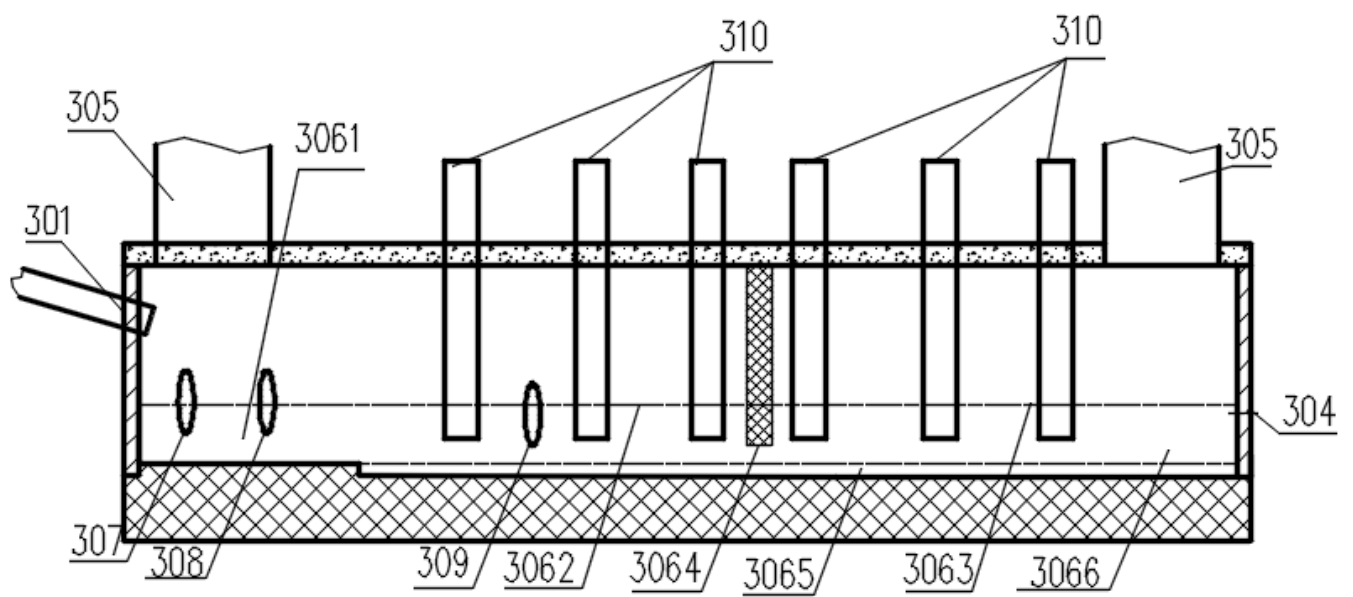


Fig. 8

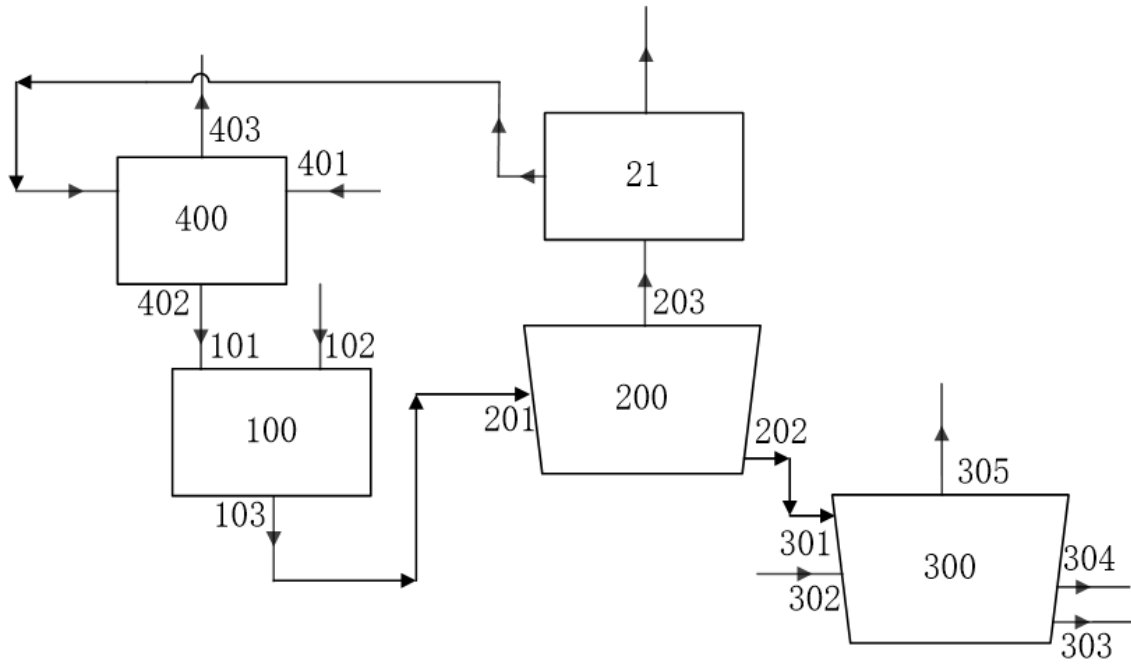


Fig. 9

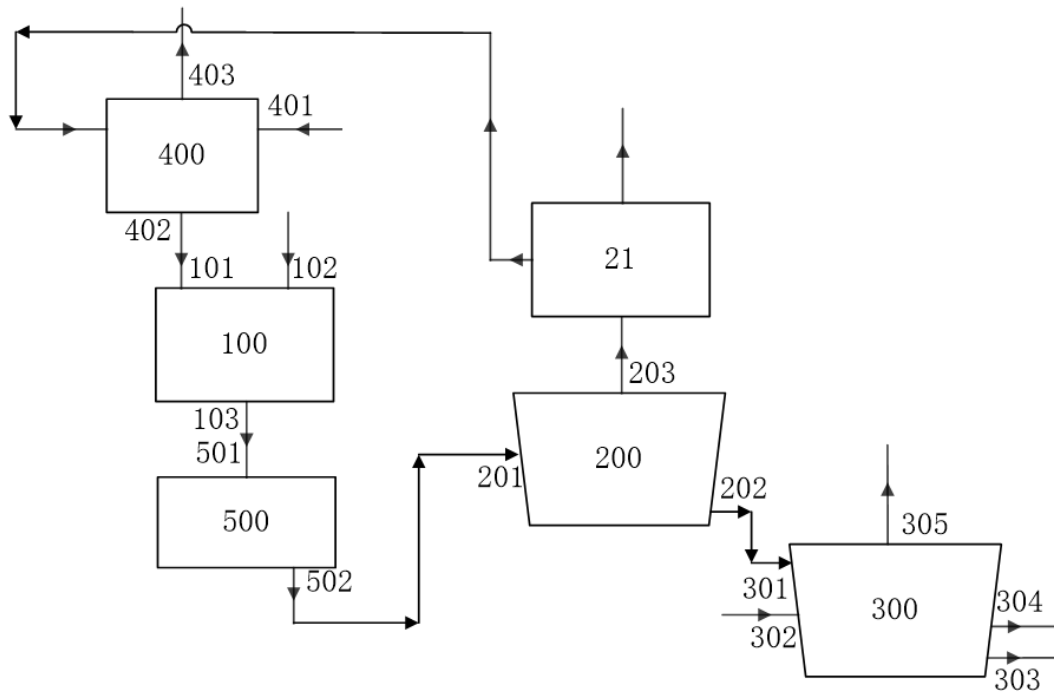


Fig. 10

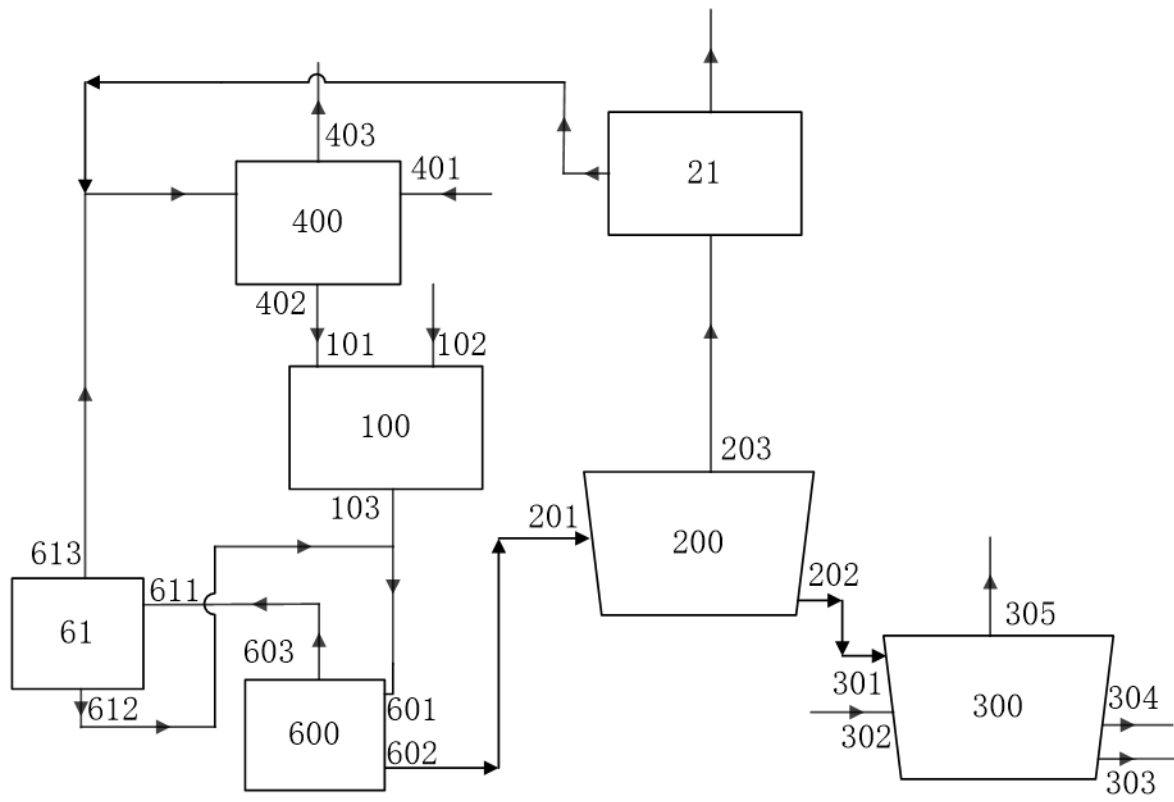


Fig. 11

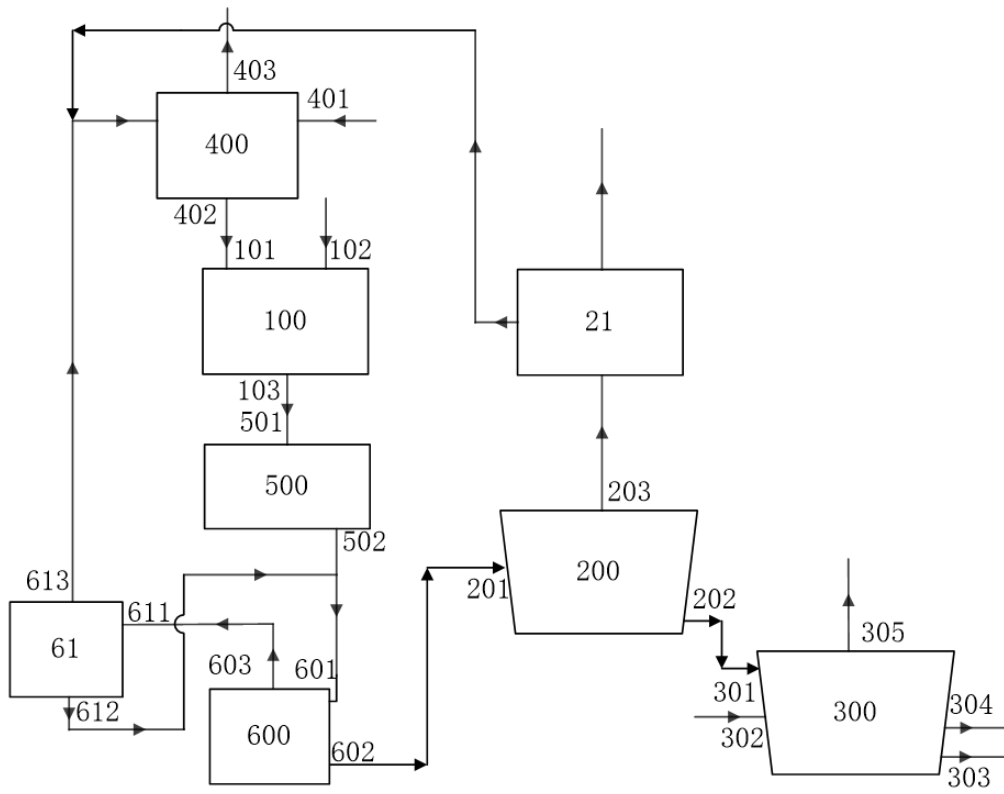


Fig. 12

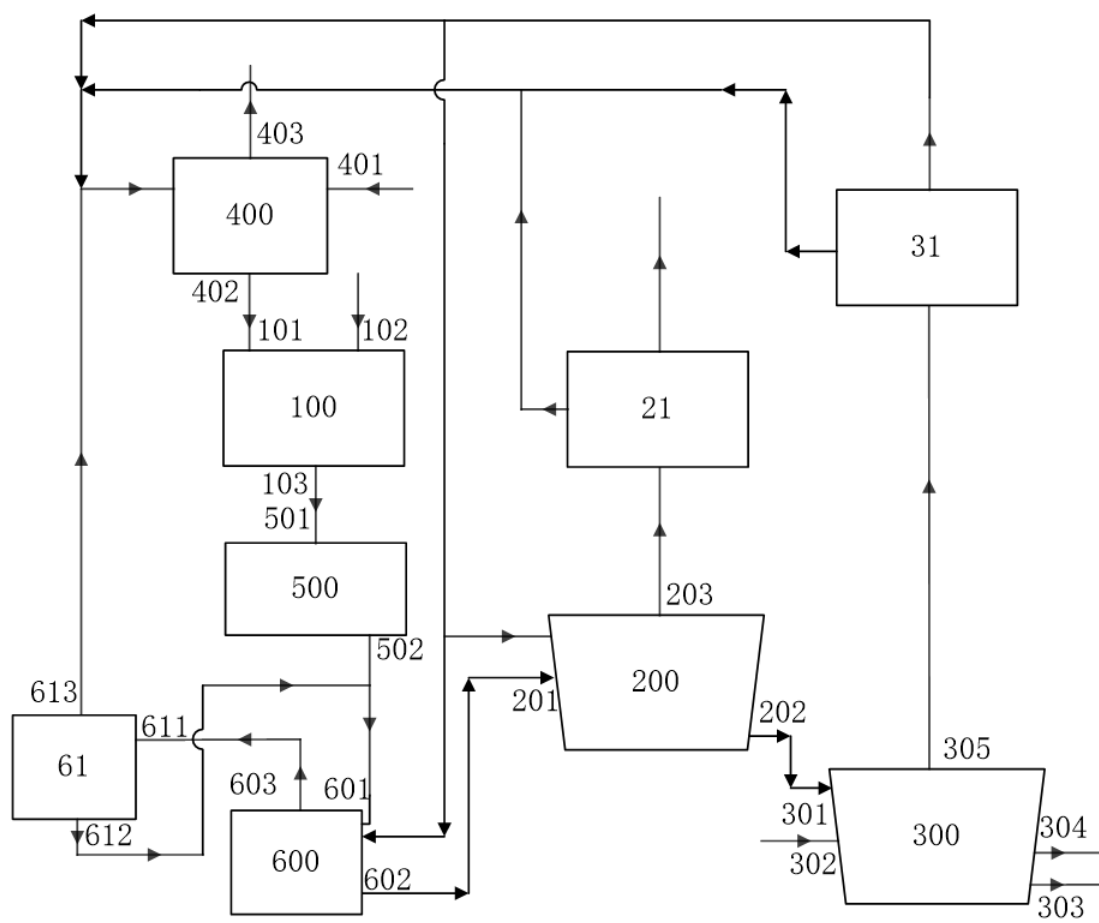


Fig.13