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(54) **PROCESS AND FACILITY FOR THERMAL TREATMENT OF A SULFUR-CONTAINING ORE**

VERFAHREN UND ANLAGE ZUR THERMISCHEN BEHANDLUNG EINES SCHWEFELHALTIGEN ERZES

PROCÉDÉ ET INSTALLATION POUR LE TRAITEMENT THERMIQUE D'UN MINERAI CONTENANT DU SOUFRE

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Description

[0001] The invention relates to a process and a plant for thermal treatment of a sulfur-containing ore in which the ore is calcined at temperatures of between 600 and 1200 °C in the presence of oxygen in a reactor so that between 1 and 90 % by weight of the sulfur contained in the ore is burned to sulfur dioxide and impurities contained are driven off in gaseous form, in which exhaust gas being produced and containing the sulfur dioxide is fed into a gas purification comprising at least one component and/or in which the calcined ore is fed into at least one further process stage.

[0002] With the increasing demand for raw materials metallic resources, in particularly also copper-, cobalt-, gold- and nickel-containing ores, are exploited more and more. This results in the fact that resources which can be exploited without large effort or which provide highly pure raw materials meanwhile are nearly exhausted. So today exploited resources of ores are characterized by a higher proportion of impurities, in particularly it is known that copper-, cobalt- and/or nickel-containing ores also comprise arsenic and antimony. Before melting the ore, the content of these impurities has to be reduced strongly.

[0003] For that, normally, the ore is heated at a temperature of between 600 and 1200 °C, preferably 600 to 900 °C. This operation is also referred to as calcining. By this heating also sulfur contained in the ore is burned to sulfur dioxide (SO_2), by which again heat is produced. Therefore, preferably, this process, after ignition with externally fed fuel, can be conducted in an autothermic manner.

[0004] US 3,351,462 A is directed to a process for producing metallic copper from copper concentrates containing iron sulfide and copper sulphide. The process comprises a roasting step for the copper concentrate in the presence of oxygen at a sufficiently high temperature to convert substantially all the iron sulfide to iron oxide and at least a part of the copper sulfide to copper oxide. Further, it covers a smelting step wherein the roasted concentrate is directly smelted in an electric furnace in the presence of slag forming agents and an amount of sulfur corresponding in molecular proportion to about one-sixth' of the amount of copper present. In the smelting step, temperature is sufficiently high to cause the sulfur to react with the copper oxide to reduce the copper oxide to metallic copper and to cause the iron oxide to form a molten slag with the slag-forming agents.

[0005] US 2006/230879 A1 relates to a method and a plant for the heat treatment of sulfidic ores, in which solids are heated to a temperature of approximately 450 to 1500 °C in a fluidized bed reactor. In order to improve the energy utilization, it is proposed to introduce a first gas or gas mixture from below through a gas supply tube into a mixing chamber of the reactor, the gas supply tube being at least partly surrounded by a stationary annular fluidized bed which is fluidized by supplying fluidizing gas. The gas velocities of the first gas or gas mixture as well as of the fluidizing gas for the annular fluidized bed are adjusted such that the particle Froude numbers in the gas supply tube are between 1 and 100, in the annular fluidized bed between 0.02 and 2 and in the mixing chamber between 0.3 and 30.

[0006] EP 0 508 542 A2 describes roasting of ores with metal values such as precious metal ores for recovery of metal values with conversion of arsenic to an insoluble form in-situ in presence of an additive such as iron and in presence of oxygen injected initially or supplementary in a roaster such as in a circulating fluid bed roaster; volatilized arsenic in roasting of ores may also be converted to an insoluble form in gas phase in a two stage roaster process after removal of solids from a gas phase and contact with an additive at high oxygen concentration in a second stage roaster.

[0007] Due to the higher amounts of impurities in the ore used and, connected there-with, the requirement of evaporating higher proportions, the energy demand of this process increases with the amounts of impurities in the ore. So the sulfur contained is either no longer capable of allowing an autothermic process control or a very large proportion of the sulfur contained is already consumed during this calcining process, so that into the later melt of the ore more fuel has to be fed from outside.

[0008] Therefore, it is an object of the present invention to provide a process with which the energy demand for the removal of impurities during the calcining step can be reduced.

[0009] This object is solved by a process with the features of patent claim 1.

[0010] For that a sulfur-containing ore is fed into an autothermal operated reactor and there it is thermally treated at a temperature of between 600 and 1200 °C, preferably 600 and 900 °C, particularly preferably 650 and 750 °C in the presence of oxygen. So 1 to 90 % by weight, preferably 10 to 60 % by weight of the sulfur contained in the ore is burned to sulfur dioxide and impurities contained are driven off in gaseous form. Such a process is referred to as partial calcination.

[0011] In such a case, a typical ore is characterized by the following composition:

Table 1: typical composition of ore.

Element	Range in % by weight	Preferable range in % by weight
Copper	20 - 45	25 - 35
Cobalt	0 - 5	0 - 2
Sulfur	20 - 35	25 - 30

(continued)

Element	Range in % by weight	Preferable range in % by weight
Arsenic	1 - 15	2 - 5
antimony	0 - 2	0.5 - 1
Iron	5 - 25	10 - 20

[0012] By the thermal treatment an exhaust gas is produced which contains both, the sulfur dioxide and also gaseous impurities, and which is fed into a gas purification comprising at least one component. In an alternative or in addition, it is possible to feed the calcined ore into at least one further process stage.

[0013] For autothermal conditions the energy demand in this process, either an exhaust gas from one component of the gas purification and/or an exhaust gas from the further process stage are fed into the reactor as recycling gas. During unstable process conditions, it is also possible to use a gas used for cooling before, during and/or after the gas purification and/or a gas used for cooling before, during and/or after a process stage as recycling gas or, in an even more preferred embodiment, to use coils in the reactor for a heat transfer medium. But in any case, the recycling gas must have a temperature of higher than 100 °C and thus reduce the energy demand for operating in the given temperature range by feeding it into the reactor.

[0014] Using a gas with high inlet temperature, the energy demand in the reactor is reduced so that a lower amount of sulfur being contained in the ore has to be burned. So also ores being characterized by lower contents of sulfur can be calcined more easily. When the ore in deed has a sufficient sulfur demand for the calcination, then the procedure according to the present invention is also preferable, because so the calcined ore is characterized by a higher content of sulfur which in turn can act as an internal energy supplier in downstream processing stages.

[0015] However, it is essential that the reactor is operated in an autothermic manner, i.e. that during steady operation no fuel has to be fed in or the reactor has to be cooled. This considerably reduces the effort in connection with the required equipment, because in this manner no fuel has to be fed into the reactor. The autothermic operation is realized by burning a sufficient amount of sulfur which is also contained in the ore to SO_2:

$$S + O_2 \text{ ---> } SO_2,\ \Delta H_R = -297.03 \text{ kJ}.$$

[0016] Preferably, in this case the temperature in the reactor is controlled by the amount of oxygen which is fed in, because the amount of sulfur which can be burned depends on the oxygen being available.

[0017] Preferably, the driven off impurities contain arsenic and/or antimony in amounts of between 0.1 and 10 % by weight, preferably 0.5 and 5 % by weight, based on the composition of the ore being fed into the reactor. Arsenic and antimony are compounds which in particularly at temperatures of between 650 and 750 °C evaporate and thus can be discharged in gaseous form. At the same time, arsenic and antimony are highly toxic and thus have to be removed from the ore as early as possible.

[0018] Preferably, the ore contains in addition at least 20 % by weight of copper, cobalt, gold and/or nickel, whereby the conduction of the process according to the present invention is particularly cost-effective.

[0019] Furthermore, it was shown to be advantageous, when the reactor is operated as a fluid bed reactor. In this case it is particularly favorable, when the recycling gas is fed into the fluid bed as fluidization gas. On the one hand, so the gas amount for the fluid bed is created in advance, and on the other hand, the problem that the reactor is cooled down by cold fluidization air does not exist.

[0020] Preferably, the recycling gas has a temperature of between 200 and 500 °C, particularly preferably between 300 and 450 °C, because in this manner as much as possible heat is introduced into the reactor. At the same time, the temperature of the gas is not so high that the required equipment would be subjected to temperatures which are too high and thus correspondingly would be more cost-intensive to purchase.

[0021] Furthermore, it was shown to be advantageous, when the recycling gas has a proportion of oxygen of between 3 and 20 % by weight. When the reaction procedure is conducted according to the present invention, then such a proportion of oxygen is sufficient for operating the reactor at the required temperatures in an autothermic manner. A further advantage of the invention is that due to the fact that now a lower amount of sulfur has to be burned for achieving the required temperatures also the amount of oxygen which has to be provided for the reaction is lower. However, by a decrease of the oxygen content it is possible to reliably avoid the formation of arsenic and/or antimony oxides, which cannot be removed from the ore in gaseous state any longer and thus remain in it and reduce the quality thereof.

[0022] Furthermore, it was shown to be advantageous, when the recycling gas is a mixture of several exhaust gases and/or gases which are used for cooling. In particular a mixture in which the oxygen content is adjusted in a targeted manner to the desired temperature in the reactor due to the burning of sulfur is a mixture which is of advantage.

[0023] In addition, it was shown to be favorable, when after the reactor the ore is fed into a process stage being designed as a melt and gases from this melt and/or from a downstream cooling are returned back into the reactor as recycling gas or constituent of the recycling gas. In particular, the advantage is that the melt is realized at very high temperatures (> 1200 °C) so that also cooling and/or exhaust gases from the melt are characterized by correspondingly high temperatures and a total gas flow which is smaller has to be returned back, since it is already characterized by a very high content of energy. Here it is also imaginable that small amounts of very hot cooling and/or exhaust gases from the melt are fed in before the reactor and there are mixed with fresh air so that the temperature of the gas is not an unnecessary burden for the parts of the plant, but the returned gas flow is smaller and thus the design of the required equipment may be characterized by smaller dimensions.

[0024] A preferable design of the invention is characterized by a gas purification which comprises a process for producing sulfuric acid from sulfur dioxide being contained in the exhaust gas. Such a process for producing sulfuric acid is, for example, described in DE 10 2005 008109 A1. Such a process releases relatively much energy, so that it is of advantage to reuse this energy for calcination in the form of the recycling gas.

[0025] Preferably, in such a process under heterogeneous catalysis with addition of air at first SO_2 is reacted to SO_3. In this case, the source of oxygen is air. Besides SO_3, from this reaction also a gas which is poor in oxygen results, wherein poor in oxygen in the sense of the invention means a proportion of oxygen which is lower than 21 % by volume, preferably lower than 18 % by volume. This gas which is poor in oxygen, according to the present invention, can then be returned back into the reactor as recycling gas or as constituent of the recycling gas, so that here the provision of oxygen is minimized and therefore the risk of forming arsenic and/or antimony oxides is considerably reduced.

[0026] When the gas purification comprises a process for producing sulfuric acid from SO_2, then, furthermore, it was shown to be favorable that the SO_3 is absorbed with sulfuric acid in at least two stages and that between two adjacent stages the sulfuric acid is guided through a heat exchanger. Such a recovery process is also described in DE 10 2005 008109 A1. According to the present invention, the heat exchanger uses air or another gas, preferably with an oxygen content of < 20 % by volume, so that the cooling gas of the heat exchanger is returned back into the reactor as recycling gas or constituent of the recycling gas.

[0027] According to the present invention, it is particularly preferable, when the sulfur dioxide is at first reacted to sulfur trioxide and subsequently the sulfur trioxide is absorbed in sulfuric acid. In this case, both, the gas which is poor in oxygen from the heterogeneous reaction of SO_2 to SO_3 and also the heated air from the at least one heat exchanger between both absorbers in the absorption stage are mixed with air so that a specific oxygen content of between 3 and 20 % by weight is adjusted, whereby the temperature in the reactor can be regulated or controlled by regulating or controlling the amount of sulfur to be burned and thus the additional energy amount through the oxygen content.

[0028] In addition, it is also imaginable to burn sulfur yet in addition during the production of sulfuric acid. The heat resulting from this burning can also be used for the partial calcination, either directly in the form of the exhaust gas or indirectly as vapor.

[0029] Furthermore, a plant is designed for conducting a process with the features of patent claims 1 to 12.

[0030] Such a facility for thermal treatment of a sulfur-containing ore comprises an autothermal reactor in which the ore is calcined at temperatures of between 600 and 1200 °C, preferably 600 and 900 °C, particularly preferably 650 to 750 °C in the presence of oxygen. Furthermore, such a facility comprises at least one component of a gas purification and/or a further process stage for treating the ore.

[0031] Furthermore, according to the present invention, the facility comprises a return line from at least one component of the gas purification and/or the further process stage and/or a return line from a cooling within the gas purification and/or a cooling for the further process stage. So heated gas as recycling gas can be returned back into the reactor for calcining, whereby, in addition to the burning of sulfur, the required energy input is reduced. So, on the one hand, the oxygen content in the calcining reactor can be reduced which decreases the risk of forming oxides which can be removed only with high effort, and, on the other hand, so a lower amount of sulfur has to be burned. Therefore, it is possible to process ore with a sulfur content which is not sufficient for achieving the required temperature at all, or the sulfur content of the calcined ore remains higher so that the ore in downstream process stages can be processed better due to the inherent energy content.

[0032] It is particularly preferable, when the reactor is designed as a fluidized bed reactor, because such a fluidized bed reactor results in very homogenous conditions throughout the whole fluidized bed.

[0033] However, in principle, it is also imaginable to conduct the reaction in a rotary kiln or a multiple-hearth furnace.

[0034] In a preferred embodiment, cooling coils are foreseen. This is particular preferred for a fluidized bed reactor wherein the coils at least partly are immersed into the fluidized bed during operation, but it is not restricted to this reactor type. With these cooling coils, instable process conditions as well as start-up and shut down of the plant can be handled.

[0035] In the following, the invention is explained in more detail by means of a figure. Here, all described and/or depicted features form on its own or in arbitrary combination the subject matter of the invention, independently from their summary in the patent claims or their back reference.

[0036] Fig. 1 shows a procedure according to the present invention in a schematic manner.

[0037] In Fig. 1 via line 1 an ore is introduced into the reactor 10 which has the following composition:

Table 2: composition of the introduced ore.

Element	% by weight
Cu	28.1
Fe	12.9
S	24.5
As	3.3
Sb	0.1
Pb	< 0.1
Zn	0.6
Ag	< 0.1

[0038] But similarly the described process is also possible for each ore composition mentioned in table 1.

[0039] In reactor 1 the ore is thermally treated in a so-called calcining process at temperatures of between 550 and 1000 °C, preferably 680 and 720 °C under autothermal conditions. Here, on the one hand, sulfur contained in the ore is burned so that SO_2 and heat are formed. On the other hand, at the prevailing reaction temperatures impurities, in particularly arsenic and/or antimony, are evaporated which is an energy consuming process. Exhaust gases consisting of the introduced air, the produced SO_2 and gaseous impurities are subsequently drawn off via line 11 and are fed into a cyclone 20.

[0040] In this cyclone 20 the particles entrained by the exhaust gas flow are separated from the gas flow. The so purified gas from which dusts and small particles (< 20 μm) have been removed is then fed into a gas purification 22.

[0041] The gas purification 22, preferably, comprises a hot filtration and/or a quench, preferably with water, and/or a wet filtration and/or a mercury removal and/or a gas drying, particularly preferably in this arrangement. Exhaust gases which are produced so and/or a gas which is used for cooling of one of the mentioned gas components or between the mentioned gas purification components can then be returned back into the reactor 10 via lines 23, 41 and 40 as recycling gas, wherein this recycling gas has a temperature of higher than 100 °C, preferably 300 to 450 °C.

[0042] Furthermore, the gas from the gas purification facility 22 or also directly from line 21 is fed into a sulfur trioxide reactor 30 via line 23 for reacting SO_2 to SO_3 in a heterogeneously catalyzed reaction. The oxygen required for this reaction is introduced via line 31. Similarly, also an introduction into lines 22 or 23 would be imaginable. The exhaust gas which is produced and which is oxygen-depleted, since oxygen from air has been used for the reaction of SO_2 to SO_3, is fed as recycling gas into reactor 10 via line 42 and line 40.

[0043] Via line 32 the produced SO_3 is fed into at least one absorption stage 33. Into this absorption stage 33 via line 34 sulfuric acid is introduced and via line 35 drawn off again. In the sulfuric acid SO_3 and H_2SO_4 form disulfuric acid $H_2S_2O_7$ which in contact with water decomposes into two molecules of sulfuric acid. This product is drawn off via line 35.

[0044] Preferably, as shown, the absorption is characterized by a design of at least two stages so that line 35 does not immediately withdraw the end product, but does it fed into a second absorption stage 36 from which then the end product is drawn off via line 37. In line 35 a heat exchanger 39 is located which also uses a gas, preferably air, as a heat carrier medium. So the air fed via line 38 into the heat exchanger 39 can be heated and it can be fed into recycling line 40 via line 44, 43. Similarly, also the use of a process gas which is poor in oxygen instead of air would be imaginable.

[0045] Preferably, gas which is poor in oxygen, thus gas with an oxygen content of between 5 and 20 % by weight, preferably 8 to 14 % by weight is drawn off from the sulfur trioxide reactor 30 via line 42. This step of drawing off can also be realized via a chimney (not shown), thus after passing both absorption stages. By mixing the gases in lines 42 and 44 the oxygen content in lines 43, 40, optionally also by further admixing via line 41, can be controlled or regulated. A definition of the oxygen content also results in the stoichiometrically possible conversion of sulfur in reactor 10, whereby in this manner also the amount of heat generated by the burning of sulfur and thus finally the temperature in reactor 10 can be controlled.

[0046] The ore is drawn off from reactor 10 via line 12. Preferably, into it the particles and fine dusts separated in cyclone 20 are fed by means of line 24. Then, the ore can be used elsewhere or it can be directly further processed in a cluster of production plants.

[0047] In an alternative or in addition to the described recycling gas guidance from the gas purification, when the further processing is conducted on-site, it is possible to recover recycling gas also in a downstream ore processing

stage. Preferably, in this case, the ore is fed into a melting furnace 50 via line 51 in which the ore is further purified. Exhaust gases which are produced here and originate either directly from the melting furnace 50 or also from a cooling downstream of the melting furnace 50 (not shown) can be fed into reactor 10 via a recycling gas line 60.

[0048] Similarly, also other stages for further processing the ore are imaginable from which either directly gas and/or cooling gas used in a corresponding cooling can be used as recycling gas or as constituent of the recycling gas. In the shown process, at the same time, the melting furnace is cooled and via the same recycling gas line in its function as a heat carrier medium also heated gas is returned back into reactor 10.

[0049] Furthermore, generally, it is also imaginable to mix the recycling gas from recycling gas line 60 independently from its origin with the recycling gas from line 40.

[0050] Preferably, reactor 10 is designed as a fluidized bed reactor so that the recycling gas is used completely or partially as fluidization gas. In this case, both, a stationary fluidized bed and also a circulating fluid bed are possible.

List of reference signs

[0051]

1	line
10	reactor
11, 12	line
20	cyclone
21	line
22	gas purification stage
23	line
30	sulfur trioxide reactor
31, 32	line
33	absorption stage
34, 35	line
36	absorption stage
37, 38	line
39	heat exchanger
40-44	line
50	melting furnace
51	line
60	line

Claims

1. A process for thermal treatment of a sulfur-containing ore in which the ore is calcined at temperatures of between 600 and 1200 °C in the presence of oxygen in a reactor so that between 1 and 90 % by weight of the sulfur contained in the ore is burned to sulfur dioxide and impurities contained are driven off in gaseous form, in which exhaust gas being produced and containing the sulfur dioxide is fed into a gas purification comprising at least one component wherein an exhaust gas from the gas purification is at least partially returned back into the reactor as recycling gas having a temperature of > 100 °C and that the reactor is operated in an autothermic manner.

2. The process according to claim 1, **characterized in that** the calcined ore is fed into at least one further process stage, and that an exhaust gas from the process stage and/or a gas used for cooling within the further process stage is at least partially returned back into the reactor as recycling gas having a temperature of > 100 °C.

3. The process according to claim 1 or 2, **characterized in that** the driven off impurities arsenic and/or antimony are contained in amounts of between 1 and 10 % by weight, based on their content in the sulfur-containing ore used, and/or that the ore contains at least 70 % by weight of copper, cobalt, gold and/or nickel.

4. The process according to one of the preceding claims, **characterized in that** the oxygen content of the recycling gas is used as command or control variable for controlling or regulating the temperature in the reactor.

5. The process according to one of the preceding claims, **characterized in that** the recycling gas is used as fluidization gas in the reactor being designed as a fluid bed reactor or as combustion air in the reactor being designed as a

rotary kiln.

6. The process according to one of the preceding claims, **characterized in that** the recycling gas has a temperature of between 100 and 600 °C.

7. The process according to one of the preceding claims, **characterized in that** the recycling gas has a proportion of oxygen of between 3 and 20 % by weight.

8. The process according to one of the preceding claims, **characterized in that** the recycling gas is a mixture of several exhaust gases and/or gases which are used for cooling.

9. The process according to one of the preceding claims, **characterized in that** the ore after the reactor is fed into a melt and exhaust gas from this melt and/or a gas from a cooling downstream of it is returned back into the reactor as recycling gas or constituent of the recycling gas.

10. The process according to one of the preceding claims, **characterized in that** the gas purification comprises a process for producing sulfuric acid from the sulfur dioxide contained in the exhaust gas and from this process gas is returned back into the reactor as recycling gas or constituent of the recycling gas.

11. The process according to claim 10, **characterized in that** the SO_2 with addition of air is reacted to SO_3 and a gas which is poor in oxygen and that the gas which is poor in oxygen is returned back into the reactor as recycling gas or constituent of the recycling gas.

12. The process according to claim 11, **characterized in that** the SO_3 is absorbed with sulfuric acid in at least two stages, that the sulfuric acid between two series-connected stages is guided through at least one heat exchanger, that in this heat exchanger air is used as heat transport medium and that this air is returned back into the reactor as recycling gas or constituent of the recycling gas.

13. The process according to claim 12, **characterized in that** gas which is poor in oxygen from the reaction of SO_2 to SO_3 and heated air from the at least one heat exchanging between both absorption stages are mixed such that a specific oxygen content of between 3 and 20 % by weight is adjusted with which the temperature in the reactor is controlled or regulated.

Patentansprüche

1. Verfahren zur thermischen Behandlung eines schwefelhaltigen Erzes, bei dem das Erz bei Temperaturen zwischen 600 und 1200 °C in Gegenwart von Sauerstoff in einem Reaktor kalziniert wird, so dass zwischen 1 und 90 Gew.-% des im Erz enthaltenen Schwefels zu Schwefeldioxid verbrannt werden und enthaltene Verunreinigungen gasförmig ausgetrieben werden, bei dem anfallendes, das Schwefeldioxid enthaltendes Abgas einer Gasreinigung mit mindestens einer Komponente zugeführt wird, wobei ein Abgas aus der Gasreinigung als Recyclinggas mit einer Temperatur von > 100 °C zumindest teilweise in den Reaktor zurückgeführt wird und der Reaktor autotherm betrieben wird.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** das kalzinierte Erz in mindestens eine weitere Prozessstufe eingespeist wird und dass ein Abgas aus der Prozessstufe und/oder ein zur Kühlung innerhalb der weiteren Prozessstufe verwendetes Gas als Recyclinggas mit einer Temperatur von > 100 °C zumindest teilweise in den Reaktor zurückgeführt wird.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die ausgetriebenen Verunreinigungen Arsen und/oder Antimon in Mengen zwischen 1 und 10 Gew.-%, bezogen auf ihren Gehalt in dem eingesetzten schwefelhaltigen Erz, enthalten sind und/oder dass das Erz mindestens 70 Gew.-% Kupfer, Kobalt, Gold und/oder Nickel enthält.

4. Verfahren nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** der Sauerstoffgehalt des Recyclinggases als Steuer- oder Regelvariable zur Steuerung oder Regelung der Temperatur im Reaktor verwendet wird.

5. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Recyclinggas als Fluidisierungsgas in dem als Wirbelschichtreaktor ausgelegten Reaktor oder als Verbrennungsluft in dem als Drehrohrofen ausgelegten Reaktor verwendet wird.

6. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Recyclinggas eine Temperatur zwischen 100 und 600 °C hat.

7. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Recyclinggas einen Sauerstoffanteil zwischen 3 und 20 Gew.-% aufweist.

8. Verfahren nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** das Recyclinggas ein Gemisch aus mehreren Abgasen und/oder Gasen ist, die zur Kühlung verwendet werden.

9. Verfahren nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** das Erz nach dem Reaktor in eine Schmelze eingespeist wird und Abgas aus dieser Schmelze und/oder ein Gas aus einer nachgeschalteten Kühlung als Recyclinggas oder Bestandteil des Recyclinggases in den Reaktor zurückgeführt wird.

10. Verfahren nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** die Gasreinigung ein Verfahren zur Herstellung von Schwefelsäure aus dem im Abgas enthaltenen Schwefeldioxid umfasst und aus diesem Prozessgas als Recyclinggas oder Bestandteil des Recyclinggases in den Reaktor zurückgeführt wird.

11. Verfahren nach Anspruch 10, **dadurch gekennzeichnet, dass** das SO_2 unter Zugabe von Luft zu SO_3 und einem sauerstoffarmen Gas umgesetzt wird und dass das sauerstoffarme Gas als Recyclinggas oder Bestandteil des Recyclinggases wieder in den Reaktor zurückgeführt wird.

12. Verfahren nach Anspruch 11, **dadurch gekennzeichnet, dass** das SO_3 in mindestens zwei Stufen mit Schwefelsäure absorbiert wird, dass die Schwefelsäure zwischen zwei in Reihe geschalteten Stufen durch mindestens einen Wärmetauscher geführt wird, dass in diesem Wärmetauscher Luft als Wärmetransportmedium verwendet wird und dass diese Luft als Recyclinggas oder Bestandteil des Recyclinggases wieder in den Reaktor zurückgeführt wird.

13. Verfahren nach Anspruch 12, **dadurch gekennzeichnet, dass** sauerstoffarmes Gas aus der Reaktion von SO_2 zu SO_3 und erwärmte Luft aus dem mindestens einen Wärmeaustausch zwischen den beiden Absorptionsstufen so gemischt werden, dass ein spezifischer Sauerstoffgehalt zwischen 3 und 20 Gew.-% eingestellt wird, mit dem die Temperatur im Reaktor gesteuert oder geregelt wird.

Revendications

1. Procédé de traitement thermique d'un minerai contenant du soufre dans lequel le minerai est calciné à des températures comprises entre 600 et 1 200 °C en présence d'oxygène dans un réacteur de sorte qu'entre 1 et 90 % en poids du soufre contenu dans le minerai sont brûlés en dioxyde de soufre et les impuretés contenues sont chassées sous forme de gaz, dans lequel le gaz d'échappement qui est produit et qui contient le dioxyde de soufre est introduit dans une purification de gaz comprenant au moins un composant dans lequel un gaz d'échappement de la purification de gaz est au moins partiellement renvoyé dans le réacteur en tant que gaz de recyclage ayant une température > 100 °C et le réacteur est exploité d'une manière autothermique.

2. Procédé selon la revendication 1, **caractérisé en ce que** le minerai calciné est introduit dans au moins une autre étape du procédé, et **en ce qu'**un gaz d'échappement provenant de l'étape du procédé et/ou un gaz utilisé pour le refroidissement au sein de l'autre étape du procédé est au moins partiellement renvoyé dans le réacteur en tant que gaz de recyclage ayant une température > 100 °C.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** les impuretés d'arsenic et/ou antimoine chassées sont contenues en des quantités comprises entre 1 et 10 % en poids, sur la base de leur teneur dans le minerai contenant du soufre utilisé, et/ou **en ce que** le minerai contient au moins 70 % en poids de cuivre, de cobalt, d'or et/ou de nickel.

4. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la teneur en oxygène du gaz de recyclage est utilisée comme variable de commande ou de contrôle pour le contrôle ou la régulation de la

température dans le réacteur.

5. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le gaz de recyclage est utilisé comme gaz de fluidisation dans le réacteur qui est conçu comme un réacteur à lit fluidisé ou comme air de combustion dans le réacteur qui est conçu comme un four tournant.

6. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le gaz de recyclage a une température comprise entre 100 et 600 °C.

7. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le gaz de recyclage a une proportion d'oxygène comprise entre 3 et 20 % en poids.

8. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le gaz de recyclage est un mélange de plusieurs gaz d'échappement et/ou gaz qui sont utilisés pour le refroidissement.

9. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le minerai après le réacteur est introduit sous forme d'un fondu et un gaz d'échappement provenant de ce fondu et/ou un gaz provenant d'un refroidissement en aval de celui-ci est renvoyé dans le réacteur en tant que gaz de recyclage ou constituant du gaz de recyclage.

10. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la purification de gaz comprend un procédé de production d'acide sulfurique à partir du dioxyde de soufre contenu dans le gaz d'échappement et à partir de cela le gaz du procédé est renvoyé dans le réacteur en tant que gaz de recyclage ou constituant du gaz de recyclage.

11. Procédé selon la revendication 10, **caractérisé en ce que** du SO_2 avec l'ajout d'ajout est transformé par réaction en SO_3 et un gaz qui est pauvre en oxygène et **en ce que** le gaz qui est pauvre en oxygène est renvoyé dans le réacteur en tant que gaz de recyclage ou constituant du gaz de recyclage.

12. Procédé selon la revendication 11, **caractérisé en ce que** le SO_3 est absorbé avec de l'acide sulfurique dans au moins deux étapes, **en ce que** l'acide sulfurique entre deux étapes reliées en série est guidé à travers au moins un échangeur de chaleur, **en ce que** cet air de l'échangeur de chaleur est utilisé comme milieu caloporteur et **en ce que** cet air est renvoyé dans le réacteur en tant que gaz de recyclage ou constituant du gaz de recyclage.

13. Procédé selon la revendication 12, **caractérisé en ce que** le gaz qui est pauvre en oxygène provenant de la réaction de SO_2 en SO_3 et l'air chauffé provenant de l'au moins un échange de chaleur entre les deux étapes d'absorption sont mélangés de sorte qu'une teneur en oxygène spécifique comprise entre 3 et 20 % en poids est ajustée avec laquelle la température dans le réacteur est contrôlée ou régulée.

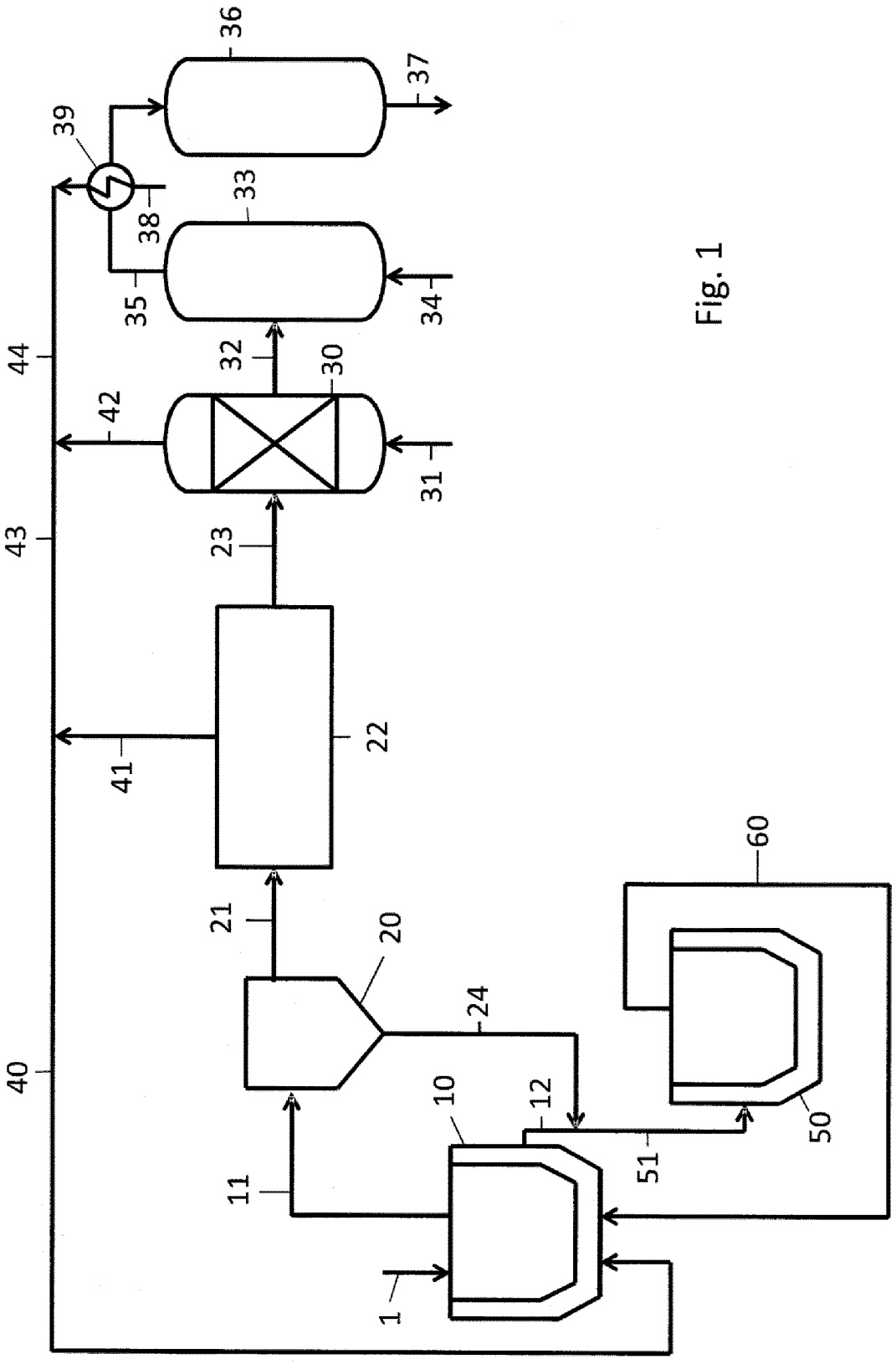
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Fig. 1

REFERENCES CITED IN THE DESCRIPTION

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