

(19)



(11)

EP 4 826 293 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.10.2026 Bulletin 2026/43

(51) International Patent Classification (IPC):
F23G 5/12 (2006.01) **F23G 5/20** (2006.01)
F23L 7/00 (2006.01)

(21) Application number: **25170536.4**

(52) Cooperative Patent Classification (CPC):
F23G 5/12; F23G 5/20; F23L 7/007;
F23C 2900/06041; F23G 2203/20; F23G 2204/101;
F23G 2204/103; F23L 2900/07005

(22) Date of filing: **15.04.2025**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA

Designated Validation States:

GE KH LA MA MD TN

(71) Applicant: **Linde GmbH**
82049 Pullach (DE)

(72) Inventors:
• **Ritzén, Ola**
18494 Åkersberga (SE)

• **Frank, Eric**
19138 Sollentuna (SE)
• **Muren, David**
185 39 Vaxholm (SE)
• **Nyman, Fredrik**
112 67 Stockholm (SE)

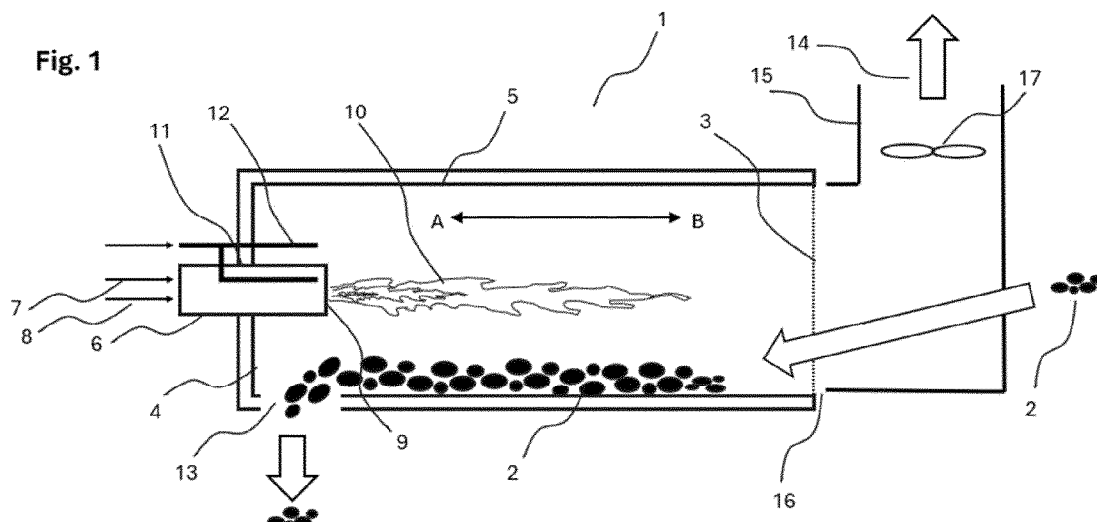
(74) Representative: **Gellner, Bernd**
Linde GmbH
Intellectual Property EMEA
Dr.-Carl-von-Linde-Straße 6-14
82049 Pullach (DE)

(54) **METHOD FOR PROCESSING A MATERIAL IN A FURNACE**

(57) The invention relates to a method for processing a material in a furnace, the furnace being enclosed by a frontal, a backwall and one or more lateral walls. A fuel and a primary oxidant are fed into the furnace through a burner provided in said backwall of the furnace. At least one first gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of at least one first lance pro-

vided in said backwall and at least one second gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of at least one second lance provided in said backwall. The first lance is located closer to the center of the burner outlet than the second lance and the velocity of the first gaseous stream is less than the velocity of the second gaseous stream.

Fig. 1



EP 4 826 293 A1

Description

[0001] The present invention relates to a method for processing a material in a furnace, the furnace being enclosed by a front side, a backwall and one or more lateral walls, wherein a fuel and a primary oxidant are fed into the furnace through a burner having a burner outlet, the fuel and the primary oxidant are reacting in a main combustion reaction, wherein the burner is provided in said backwall of the furnace, wherein at least one first gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of at least one first lance provided in said backwall, and wherein at least one second gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of at least one second lance provided in said backwall. The invention further relates to a furnace for carrying out the method.

Background of the Invention

[0002] Many kilns, and in particular lime kilns at pulp mills in Scandinavia, have abandoned or significantly reduced their reliance on fossil fuels such as natural gas or oil and replaced such with renewable fuels. Often by-products from pulp/paper production or from sawmills, such as wood, lignin and bio-oil residues or weak combustible gases, are used as fuel. In many cases, kiln operations rely on multiple bio-fuel sources of various states, i.e. solids, liquids and gases.

[0003] Upon converting a kiln from using fossil fuel to a lower quality fuel, a reduction of approximately 10% of the kiln capacity can be expected. It is widely known that oxygen injection can support the combustion process of lower grade fuels and can restore capacity. In particular, oxygen injection is very favourable to support combustion of fuel streams containing elevated proportions of granulated solids such as wood chips, wood powder, bark powder or bark chips.

[0004] To recover capacity, oxygen assisted combustion offers a proven and low-cost technology. Oxygen lancing in its simplest forms is not a new technology in lime kilns.

[0005] Known modes of oxygen injection into a kiln can however exhibit various side effects or limitations of kiln operations.

[0006] Sole oxygen lancing inside or very close to the burner can result in hot spots near the lime surface below the burner due to intense combustion. The fuel and the lanced oxygen are close to each other. The burner may as well suffer from overtemperature due to proximity of combustion nearby processes.

[0007] Furthermore, as the oxygen lance is typically fixed in size, its momentum is determined by the flow-rate. With varying need of power in the lime kiln operation, it can be difficult to maintain a constant oxygen supply relative to the power/fuel supply without changing the velocities of the oxygen jet which governs the

nearby combustion process.

[0008] Sole oxygen injection at the backwall of the kiln where the burner at low velocity is typically mounted will practically result in general oxygen enrichment of the auxiliary air which enters the kiln through openings in lime coolers or through a general opening where burnt lime falls out of the kiln. Such mode is known to elevate NOx emissions upon high enrichment levels and provides few means to control the individual zones of the combustion process.

[0009] High velocity oxygen lancing adjacent to a burner is known to reduce NOx as it effectively dilutes oxygen with combustion products such as CO₂ and H₂O to obtain "flameless" combustion. However, such lances are typically equipped with constant diameter outlets and exhibit the same inflexibility as a lance inside a burner. Furthermore, too high velocity may extend the combustion process too far inside the kiln not providing enough heat at the very end. Additionally, flameless combustion requires high temperatures and cannot safely be used at low temperatures such as starting up a kiln after a cold shutdown.

[0010] Consequently, existing lance technologies exhibit difficulties in being very flexible throughout the entire operational range.

[0011] It is also known that mud or slag rings can form at different locations around the inner circumference of a lime kiln. The formation of such a material ring can cause several operational problems, such as negatively affect product quality or reduce throughput. In severe cases it can cause unscheduled shutdown of the kiln.

[0012] Ring formation is not uncommon and by no means limited to lime kilns. It occurs in other types of kilns, too. The ring formation depends on several factors including size and length of the kiln, composition of the processed material, fuel, moisture content of the material and the operating conditions of the kiln.

[0013] It is an object of the present invention to provide a method for operating a furnace using fuel of a lower quality, in particular using wood powder or wood chips as fuel.

[0014] It is another object of the present invention to provide a method to reduce ring formation in a furnace, especially in a kiln, and / or to rebuild an already formed ring in the furnace or kiln.

Disclosure of the invention

[0015] This object is achieved by a method for processing a material in a furnace, the furnace being enclosed by a front side, a backwall and one or more lateral walls, wherein a fuel and a primary oxidant are fed into the furnace through a burner having a burner outlet, the fuel and the primary oxidant are reacting in a main combustion reaction, wherein the burner is provided in said backwall of the furnace, wherein a first gaseous stream having an oxygen content of at least

80 % by volume is injected into the furnace by means of a first lance provided in said backwall, and wherein a second gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of a second lance provided in said backwall. The invention is characterized in that the distance between the first lance and the center of the burner outlet is less than 1.5 times the radius of the burner outlet, and that the distance between the second lance and the center of the burner outlet is more than 1.5 times the radius of the burner outlet and that the distance between the second lance and the lateral walls of the furnace is more than 20% of the diagonal of said backwall of the furnace, and that the velocity of the first gaseous stream is less than the velocity of the second gaseous stream.

[0016] Advantageous further embodiments form the subject matter of the dependent claims and of the subsequent description.

[0017] The term "furnace" shall mean a chamber, device, or structure, especially a thermally insulated chamber, device, or structure, designed and configured to achieve and maintain elevated temperatures for the controlled processing, treatment, or transformation of materials. Typical applications include, but are not limited to, the firing of ceramics, the hardening or sintering of materials, the curing of composites, the calcination of minerals, and the thermal treatment and heat treatment of various substances. The term "furnace" shall particularly include kilns. Kilns are generally characterized by their ability to subject materials to high temperatures while providing precise temperature control and uniform heat distribution.

[0018] The interior of the furnace is enclosed by a front side, a backwall and one or more lateral walls. For example, the form of the front side and of the backwall can be a rectangle, a square or a polygon. The interior of the furnace can be a cube, a cuboid or a polyeder. The front side and the backwall can also be a circle, an ellipse or an oval. In one embodiment the interior of the furnace is essentially a cylinder with a circular front side, a circular backwall and a curved lateral wall. The axis of a furnace shall refer to the central line running from the front side to the backwall. Generally, the axis describes the symmetry or alignment of the furnace.

[0019] In a preferred embodiment the furnace is a rotatable furnace or rotary furnace and in particular a rotatable kiln. The rotation axis of the rotatable furnace is preferably arranged perpendicular to the front side and to the backwall of the furnace. In many cases, the rotary furnace is a cylindrical vessel that rotates around its axis. The rotary furnace is typically inclined slightly so that the material inside moves through the furnace as it rotates. Often the flue duct of the rotary furnace is located at the backwall end of the furnace or at the front side end of the furnace. In the latter case, the front side might be provided with an opening through which the

flue gases flow from the interior of the furnace into the flue duct. The transition from the interior of the furnace to the flue duct can also be continuous. This means that there is no front wall physically limiting the interior of the furnace but the front side of the furnace is identical with the inlet opening of the flue duct.

[0020] The material processed in the furnace or kiln can include a wide variety of materials including limestone, cement raw materials, clay or gypsum, ceramics, clay-based materials, metals, metal oxides or powder metallurgy materials, organic and carbon-based materials or minerals or waste materials. In one embodiment limestone is processed in said furnace or kiln. Preferably, the material is a solid state material or it comprises solid state material.

[0021] According to the invention a fuel and a primary oxidant are fed into the furnace through a burner having a burner outlet. The burner outlet is the opening at the end of the burner where the fuel and the primary oxidant are released into the furnace.

[0022] The burner is provided in the backwall of the furnace. The fuel and the primary oxidant are reacting in a main combustion reaction. The primary oxidant is preferably air but it can also be an oxidant with an oxygen content of more than 21 vol-% (21% by volume), for example oxygen enriched air. The fuel can be a gaseous, liquid or solid fuel, for example natural gas, oil, or other types of fossil fuels. In a preferred embodiment, the fuel is or comprises a bio-fuel or renewable fuel in gaseous, liquid or solid state, for example wood powder, wood chips, lignin or bio-oil residues. Other preferred fuels are granulated solids.

[0023] The fuel and the primary oxidant are fed into the furnace through the burner. Typically, the ratio of primary oxidant to fuel is maintained below the level required for complete combustion since additional oxidant is supplied by means of the first gaseous stream and the second gaseous stream.

[0024] The first gaseous stream and the second gaseous stream have an oxygen content of at least 80% by volume (80 vol-%). Preferably, the first and / or the second gaseous stream have an oxygen content of more than 90 vol-%, more than 95 vol-% or more than 99 vol-%.

[0025] The additional supply of a high oxygen oxidant to the furnace has several advantages:

- The ignition of solid fuels becomes easier.
- Flame temperature and radiation are increased.
- The flue gas volume is decreased.
- Particle burn out is improved and flue gas losses are reduced.
- Variations in moisture content and hence fuel heating can be balanced.

[0026] Thereby, the operational stability is improved.

- Full burn out of larger wood particles is achieved.

[0027] The first gaseous stream is injected into the furnace via a first lance. The term "lance" shall mean a tubular device or a nozzle designed to introduce a gaseous stream into the furnace. The first lance is provided in the backwall, that means in the same furnace wall where the burner is located. The distance between the first lance and the center of the burner outlet is less than 1.5 times the radius of the burner outlet. For a non-circular burner outlet the term "radius" shall refer to half of the longest straight line connection between two points on the boundary of the burner outlet. The first lance can be located within the burner or outside the burner. In any case the first gaseous stream is injected into the furnace close to the primary oxidant and to the fuel.

[0028] The second gaseous stream is injected into the furnace by means of a second lance. The second lance is also provided in the backwall where the burner is located. The distance between the second lance and the center of the burner outlet is more than 1.5 times the radius of the burner outlet. That means, the second lance is provided farther from the burner outlet than the first lance. The second gaseous stream is injected outside the burner and it is more distant from the center of the burner outlet than the first gaseous stream.

[0029] On the other hand, the second gaseous stream shall not be injected too close to the lateral walls, for example to the floor, of the furnace. In many cases the material supplied to the furnace contains significant amounts of dust. If the second gaseous stream flows too close to the floor or to the lateral walls of the furnace, there is a considerable risk that the dust is blown up and negatively affects visual or camera supervision of the combustion process. Therefore, the present invention proposes to provide the second lance in the backwall of the furnace such that its distance from the lateral walls is more than 20% of the diagonal of said backwall of the furnace. For a non-circular backwall the term "diagonal" shall refer to the longest straight-line segment that can be drawn between two points on the boundary of the backwall.

[0030] Finally, according to the invention the second gaseous stream is injected into the furnace at a higher velocity than the first gaseous stream. The different velocities of the first gaseous stream and the second gaseous stream enable additional degree of freedom with respect to the location of energy release. The first gaseous stream is located closer to the burner and has a lower velocity than the second gaseous stream. Therefore, the reaction between fuel and the first gaseous stream will take place closer to the backwall whereas the reaction between the fuel and the second gaseous stream will be located more distant from the backwall. By modulating the flow of the first and / or second gaseous stream the location of the combustion reaction can be shifted.

[0031] The invention proposes to provide at least one first gaseous stream and at least one second gaseous

stream. It is also possible to have two, three or more first lances and / or two, three or more second lances. The use of two or more first lances and / or two or more second lances provides improved control of the location of the combustion reaction in a direction parallel to the furnace axis as well as in a direction perpendicular to the furnace axis.

[0032] The inventive method allows to modulate the oxidant flow distribution between the primary oxidant, the first gaseous stream and the second gaseous stream. Thereby, the temperature profile and/or the local gas/material equilibrium in the furnace can be modified. As described in the introductory part of the description, the so-called "ring formation" in kilns depends on several factors including size and length of the kiln, composition of the processed material, fuel, moisture content of the material and the operating conditions of the kiln. The inventive modulation of the oxidant flows allows to prevent or reduce that ring formation, for example by changing the flow conditions such that the main combustion reaction is shifted between different locations in the furnace.

[0033] The invention proposes to inject a first and a second gaseous stream at different velocity and with different momentum. This dual momentum lancing has proven the possibility to change the heat release distribution in the furnace. Thereby, the inventive dual momentum lancing provides means for controlling and reducing the ring formation in furnaces. Furthermore, the total NOx formation can be reduced.

[0034] In an embodiment of the invention the flowrates of the first gaseous stream and of the second gaseous stream are controlled such that the fuel is combusted close to the burner. This can be achieved by increasing the flowrate of the first gaseous stream relative to the second gaseous stream and / or by reducing the velocity of the first gaseous stream. The resulting combustion of the fuel will then be near the burner tip. This is in particular advantageous to support combustion at a cold start of the burner and may completely remove the need to use high quality fuel for ignition and heat up.

[0035] Further advantages of the combustion reaction taking place near the burner tip are to increase the temperature to avoid clogging of fuel sources, to increase temperatures to support liquid fuel droplets to completely vaporize prior to hitting the surface of the material to be processed in the furnace and to enhance combustion of solid fuels due to improved gasification and char burnout.

[0036] In lime kilns the combustion reaction near the burner tip can locally and quickly increase temperature on the lime batch material to increase CaCO_3 burnout. Further, it reduces the risk of agglomerating unfavourably large lime clusters (due to incorporation of oily residues inside the kiln) for subsequent dissolution steps outside the lime kiln. Further, it can prevent damage to the burner and / or to the first and second

lances due to large falling blocks of lime which can temporarily stick to the kiln wall.

[0037] On the other hand, the invention allows to shift the combustion reaction to a location separated from and more distant to the burner outlet. Thereby, flameless combustion can be achieved which reduces NO_x . In general, enhanced oxygen injection via the second gaseous stream provides means to shift the combustion process along the furnace axis towards the side opposite the burner and hence to move heat release further down into the furnace.

[0038] In a preferred embodiment the velocity of the first gaseous stream is between 20 m/s and 200 m/s. The minimum velocity of the first gaseous stream is 20 m/s, 30 m/s, 50 m/s or 70 m/s. The maximum velocity of the first gaseous stream is 200 m/s, 180 m/s, 150 m/s or 100 m/s.

[0039] The first lance is designed to obtain a preferred outlet diameter and is preferably positioned so that the momentum generated by the first gaseous stream is sufficient to avoid direct coalescence of the oxygen of the first gaseous stream and the fuel jet or fuel jets. Furthermore, the oxygen should have enough momentum to be efficiently dispersed and start to coalesce with the fuel downstream of the burner, approximately, at a distance of earliest $\frac{1}{2}$ burner outlet diameter. Preferably, the oxygen should carry enough momentum to effectively pull in a considerable proportion of the fuel at $\frac{1}{2}$ burner distance.

[0040] It is also preferred to set the velocity of the second gaseous stream to more than 100 m/s, more than 200 m/s or more than sonic speed. The second lance is preferably provided with a convergent-divergent nozzle or a de Laval nozzle. The nozzle may be directed parallel to the furnace axis. The nozzles of the second lance may also be directed towards the axis of the furnace.

[0041] The second lance is preferably designed to obtain very high velocities already at low flow rates and low operational power. In one embodiment the second lance is operated at high operational power and / or at high flow rates such that a choked flow is achieved.

[0042] The first gaseous stream is injected into the furnace near the burner. In an embodiment the first gaseous stream is injected into the furnace at a distance from the center of the burner outlet which is less than 1.2 times the radius of the burner outlet, less than the radius of the burner outlet or less than 0.5 times the radius of the burner outlet.

[0043] The second gaseous stream is injected into the furnace at a distance from the center of the burner outlet which is more than 1.5 times, more than 2 times or more than 3 times the radius of the burner outlet.

[0044] In another embodiment the distance between the second lance and the lateral wall(s) of the furnace is more than 20%, more than 30% or more than 40% of the diagonal of the backwall of the furnace.

[0045] In a preferred embodiment of the invention the burner is mounted in the center of the backwall.

[0046] The inventive method is particularly preferred for the use of a fuel which comprises solid material. The fuel can be a solid fuel or a combination of solid material and liquid or gaseous fuel. A preferred solid fuel consists of or comprises granulated material, for example wood chips or wood powder.

[0047] Beyond supporting solids combustion, oxygen injection is of interest to reduce the need of liquid bio-oils/residues that may be used elsewhere and hence promote furnace operation with nearly 100% solids. The inventive injection of the first and second oxygen containing stream can also mitigate the need of using very dry solid fuel sources and the need of very fine granulation of solids (that is smaller than 1 mm in general and a sizable proportion lower than 0.5 mm)

[0048] Oxygen is introduced into the furnace via the stream of primary oxidant, via the first gaseous stream and via the second gaseous stream. If there is more than one first gaseous stream and / or more than one second gaseous stream, all first and second gaseous streams are considered. Further, there is air which enters the furnace through leaks or openings. For example, in some cases a fan is placed in the flue gas duct to suck flue gases out of the furnace and at the same time suck air into the furnace through cracks or gaps or through the material outlet opening.

[0049] In one embodiment of the invention a fan is provided in the flue gas duct of the furnace. The fan is used to suck gas out of the furnace. As described above, at the same time air might be sucked into the furnace, too. This fan may be used to control the combustion process in the furnace. Therefore, the operation of the fan is preferably controlled depending on one or more of the following parameters: furnace temperature, flue gas temperature, oxygen content of the flue gas, completeness of fuel combustion, fuel burnout and / or level of calcination of limestone (if the furnace is a lime kiln).

[0050] In the following, the ratio of oxygen (in % by volume) supplied by the first and second gaseous streams to the total oxygen (in % by volume) needed for stoichiometric combustion of the fuel shall be abbreviated with POP. "POP 0" shall mean that no oxygen is supplied by the first and second gaseous streams. "POP 100" shall mean that all oxygen is supplied via the first and second gaseous streams.

[0051] In an embodiment of the invention, the total flow of oxygen supplied via the first and the second gaseous streams is maximum 60 % of the total oxygen needed for a stoichiometric combustion of the fuel supplied to the furnace (POP 60). In another embodiment the maximum flow through the first and second lances shall be limited to a level where POP 50 is reached, that is 50% of all oxygen needed for the combustion process is supplied by the first and second gaseous streams. Preferably, the total oxygen supply by the pri-

mary oxidant and by the first and second gaseous streams is selected so that the furnace operates at a POP range between 10 and 40 or at a POP range between 10 and 30 or at a POP range between 10 and 20.

[0052] According to another embodiment of the invention, the total flowrate of the first gas stream and of the second gas stream is kept constant. The primary oxidant flow can be increased, decreased or can be kept constant. In the latter case the POP value would be kept constant.

[0053] According to another embodiment one or more first gaseous streams and one or more second gaseous streams are injected into the kiln and the total flowrate of oxygen supplied via the first gas streams and via the second gas streams is between 10 vol-% and 45 vol-% of the total oxygen required for a stoichiometric combustion of the fuel supplied to the kiln.

[0054] In a preferred embodiment, there is always a minimum flow rate of the first gaseous stream and of the second gaseous stream to allow a minimum purging flow through the first and second lances in order to keep the outlets of the first and second lances and / or of their nozzles clear. This minimum purging flow is typically 5 vol-% of the maximum amount of oxygen supplied through the first and second lances (depending on the selected POP value). This minimum purging flow is not necessary if another gas is used for purging purposes.

[0055] Preferably, a process parameter, such as the furnace temperature, the temperature profile along the furnace axis, the NOx content of the flue gas and / or the level of fuel burnout, is determined and the flow of the first gaseous stream and the flow of the second gas stream are adjusted depending on the process parameter.

[0056] The flowrates of the first and the second gas streams are preferably coupled to exploit a varying degree of features as described below. The first gaseous stream and the second gaseous stream are both oxidants with a high oxygen content of at least 80 vol-%. The inventive injection of these two gaseous streams is especially beneficial to kilns fired with solid fuels, and in particular to wood fired kilns.

[0057] The oxygen injection via the first gaseous stream has the following advantages:

- Oxygen injection near the burner outlet provides combustion support and improves the cold start of the burner. The need to use high quality fuel for ignition and heat up may be completely removed.
- Oxygen injection near the burner outlet can increase temperatures to avoid clogging of fuel sources.
- Oxygen injection near the burner outlet can increase temperatures to support liquid fuel droplets to completely vaporize before they hit the surface of the material to be processed. The risk of ag-

glomerating unfavourably large lime clusters (due to incorporation of oily residues inside the kiln) for subsequent dissolution steps outside the lime kiln is minimized. Damage to the burner and / or to the first and second lances due to large falling blocks of lime which can temporarily stick to the kiln wall is prevented.

- Oxygen injection near the burner outlet can locally and quickly increase the temperature on the material to be processed and, in the case of limestone, CaCO₃ burnout is increased.
- Oxygen injection near the burner outlet also supports and enhances combustion of solid fuels due to improved gasification and char burnout.

[0058] The oxygen injection via the second high velocity gaseous stream has the following advantages:

- Oxygen injection separated from the burner can reduce NOx via flameless combustion.
- Oxygen injection separated from the burner provides means to move the combustion process along the furnace axis towards the opposite side of the burner and hence move heat release further down into the furnace in the direction of the front side.

[0059] The following observations have been made from first tests of the inventive process.

- Increased production capacity
- Reduced energy consumption
- Increased operational stability
- Increased CaO yield
- Avoiding oil-wood residue mixtures which clog the burner tip

[0060] In view of these advantages the invention is in particular beneficial for heat treatment processes in furnaces where solid fuels, low calorific fuels or low quality fuels are combusted. Compared to the prior art, the invention provides means to effectively use all advantages of the different ways of oxygen injection and / or oxygen lancing into a furnace without limiting operations with their individual disadvantages. Furthermore, having a first and a second lance provides means to control combustion beyond the limitations of the burner and enables a controlled heat release in the axial direction of the furnace.

[0061] Further advantages and embodiments of the invention will become apparent from the description and the accompanying drawings.

[0062] It should be noted that the previously mentioned features and the features to be further described in the following are usable not only in the respectively indicated combination, but also in further combinations or taken alone, without departing from the scope of the

present invention.

[0063] The invention will now be further described with reference to the accompanying drawings, which show a preferred embodiment.

Brief description of the drawings

[0064]

Fig. 1 schematically shows a rotary kiln for processing a solid material

Detailed description of the drawings

[0065] Fig. 1 schematically shows a rotary lime kiln 1 for the thermal treatment and, particularly, for calcination of limestone 2. The kiln 1 is of essentially cylindrical form with a front side 3, a backwall 4 and lateral walls 5. The front side 3 of the rotary kiln 1 is open without a frontwall. A flue gas duct 15 is directly connected to the furnace 1 so that the open front side 3 of the furnace 1 is the inlet to the flue gas duct 15. There might be a small gap 16 between the furnace 1 and the flue gas duct 15.

[0066] Limestone 2 is introduced into the lime kiln 1, usually in the form of crushed rock or pellets, and forms a bed within the rotary kiln 1.

[0067] The rotary kiln 1 maybe oriented with its axis in an essentially horizontal direction or at an angle to the horizontal with an elevated point at the limestone material input and a lower point at the limestone removal side. In this way the passage of material 2 through the kiln 1 is facilitated. After its passage through the kiln 1 the material 2 leaves the kiln 1 through an opening 13 in the lateral wall 5 close to the backwall 4 of the kiln 1.

[0068] The furnace 1 is heated by a burner 6. The burner 6 is supplied with a fuel 7 and with a primary oxidant 8, either separately or together. The primary oxidant 8 is typically air. The burner 6 is provided in the backwall 4 of the rotary kiln 1. The limestone material 2 is preferably introduced into the kiln 1 at the end opposite to the location of the burner 6, that means the material 2 is supplied at or close to the front side 3 of the kiln 1. The fuel 7 and the primary oxidant 8 leave the burner through burner outlet 9 and react in a main combustion reaction 10. The burner 6 is typically designed for an output power between 1 MW and 50 MW.

[0069] The fuel 7 is preferably a solid fuel, such as wood chips, wood powder, pulverized coal or pulverized coke or any other granulated solids, or a mixture of solid fuel and gaseous fuel. The fuel 7 can also be a liquid fuel and / or a low calorific fuel, for example a fuel from gasified wood residues, or a mixture of a low calorific fuel and a high calorific fuel.

[0070] The resulting main combustion reaction of the fuel 7 and primary oxidant 8 passes through the kiln countercurrent to the direction of the limestone material

2. The flue gas 14 leaves the kiln through the flue gas duct 15 connected to the front side 3 of the kiln 1. The produced heat is transferred to the limestone material 2 and causes the material 2 to react. For calcination of the limestone 2 a temperature between 900 °C and 1100 °C is required. To achieve the required high temperatures, the fuel is combusted with the primary oxidant and with additional gaseous oxidant supplied via one or more first lances 11 and via one or more second lances 12. For sake of clarity only one first lance 11 and one second lance 12 is shown in figure 1.

[0071] The oxidant supplied as the first gaseous stream and as the second gaseous stream has an oxygen content of at least 80 vol-% and it is preferably technical pure oxygen with a purity of more than 90 vol-%, more than 95 vol-% or more than 99 vol-%.

[0072] The burner 6 as well as the first lance(s) 11 and the second lance(s) 12 are mounted in the backwall 4 of the furnace 1. The first lance 11 is provided within the burner 6 and the first gaseous stream leaves the burner 6 through the burner outlet 9 together with the fuel 7 and the primary oxidant 8. The second lances 12 are also provided in the backwall 4 of the furnace 1 but at a larger distance from the center of the burner outlet 9 than the first lances 11. The second lances 12 may be provided with nozzles to accelerate the gaseous stream leaving the second lance(s) 12. The nozzles belonging to the second lances may preferably be of convergent-diverging type (de Laval nozzle).

[0073] The first and the second gaseous streams are lanced into the rotary kiln 1 through one or more of the lances 11, 12. Due to the different location of the first and second lances 11, 12 and due to the different velocities at which the first and second gaseous streams are introduced into the kiln 1, the first and second gaseous streams intermix with the main combustion reaction 10 at different locations in the kiln 1. This allows to control the combustion process and the flame characteristics, for example flame shape and flame intensity. By increasing the flowrate of the second gaseous stream the main combustion reaction 10 can be shifted in the axial direction of the furnace towards the front side 3. By increasing the flowrate of the first gaseous stream the main combustion reaction 10 will take place closer to the burner outlet 9. For example, in figure 1 the main heat release can be varied between point A and point B by modifying the flowrates and / or velocities of the first and the second gaseous stream 11, 12. Thereby, the conditions for the undesired ring formation are changed and ring formation can be prevented. It might even be possible to reduce an already existing ring by proper control of the first and second gaseous stream.

[0074] The total flow through the first and the second lances 11, 12 is limited to a level where POP 40 or maximum POP 50 is reached. The first lance 11 is designed to obtain a preferred outlet diameter and is preferably positioned so that the momentum generated by

the first gaseous stream is sufficient to avoid direct coalescence of the first gaseous stream and the jet of fuel 7. Furthermore, the first gaseous stream should have enough momentum to be efficiently dispersed and start to coalesce with the fuel 7 downstream of the burner, approximately, at a distance of earliest $\frac{1}{2}$ burner diameter. Preferably, the oxygen should carry enough momentum to effectively pull in a proportion of the fuel at $\frac{1}{2}$ burner distance.

[0075] The second lance 12 is preferably designed to obtain very high velocities already at low flow rates and low operational power. This may effectively result into choked flow at high operational power and high flow rates. The second lances 12 may also have nozzles that are directed towards the axis of the furnace 1.

[0076] The limestone material 2 which forms the bed in the kiln 1 may include dust or small particles. The dust and the small particles may have been introduced into the kiln 1 with the original limestone material or they may have been produced as a result of the heat treatment reactions in the kiln 1. The second gaseous stream is a high velocity gas stream and could stir up the dust or the small particles of the bed material. This would considerably interfere with the visual or camera supervision of the combustion process. Therefore, the second lance 12 is located in the backwall 4 at a distance from the lateral wall 5 of more than 20% of the diagonal of the backwall 4. In case of a cylindrical kiln 1 the diagonal is identical to the diameter of the backwall 4. At such distance from the lateral wall 5 the second gaseous stream does not upset the bed material 2.

[0077] A fan 17 can be provided in the flue gas duct 15. The speed and the operation of the fan 17 is controlled depending on the temperature and the oxygen content of the flue gas 14. The fan 17 sucks flue gas 14 out of the furnace 1 and at the same time air might be sucked into the furnace 1 through the opening 13. The air comes into contact with the hot lime stone material 2 and enters the furnace 1 as preheated air which supports the combustion of the fuel 7.

Example:

[0078] A rotary lime kiln is designed for lime production of 5 to 50 tons per hour. A solid fuel burner in the lime kiln is designed to operate in a power range of 30 to 40 MW. The amount of fuel supplied to the kiln is between 1000 and 10000 kg per hour of wood chips, wood powder or bio fuel. The total oxygen supplied to the kiln is between 200 and 5000 Nm³ per hour.

[0079] The first lance 11 is designed so that it obtains an outlet diameter to sustain a preferred minimum velocity of typically 50 m/s at the lowest intended furnace power of 30MW. About 20% of the additional oxidant (in addition to the primary oxidant 8) is supplied via the first lances 11 and about 80% of the additional oxidant is supplied via the second lances 12. At POP=30 the radius of the first lance 11 is determined to approximately

1.5 cm.

[0080] The second lance 12 is designed so that it obtains an outlet diameter to sustain a minimum velocity of typically 150 m/s at the lowest intended furnace power of 30 MW. The radius of the second lance 12 can then be determined to approximately 1.25 cm.

Claims

1. A method for processing a material in a furnace, the furnace being enclosed by a front side, a back-wall and one or more lateral walls, wherein a fuel and a primary oxidant are fed into the furnace through a burner having a burner outlet, the fuel and the primary oxidant are reacting in a main combustion reaction,

wherein the burner is provided in said backwall of the furnace,

wherein at least one first gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of at least one first lance provided in said back-wall,

wherein at least one second gaseous stream having an oxygen content of at least 80 % by volume is injected into the furnace by means of at least one second lance provided in said backwall,

characterized in that

the distance between the first lance and the center of the burner outlet is less than 1.5 times the radius of the burner outlet,

and that the distance between the second lance and the center of the burner outlet is more than 1.5 times the radius of the burner outlet

and that the distance between the second lance and the lateral walls of the furnace is more than 20% of the diagonal of said back-wall of the furnace,

and that the velocity of the first gaseous stream is less than the velocity of the second gaseous stream.

2. The method of claim 1, **characterized in that** the velocity of the first gaseous stream is between 20 m/s and 200 m/s, preferably between 30 m/s and 100 m/s.
3. The method of any one of the preceding claims, **characterized in that** the velocity of the second gaseous stream is more than 100 m/s, more than 200 m/s or more than sonic speed.
4. The method of any one of the preceding claims, **characterized in that** the second lance is provided

with a convergent-divergent type nozzle or a de Laval nozzle.

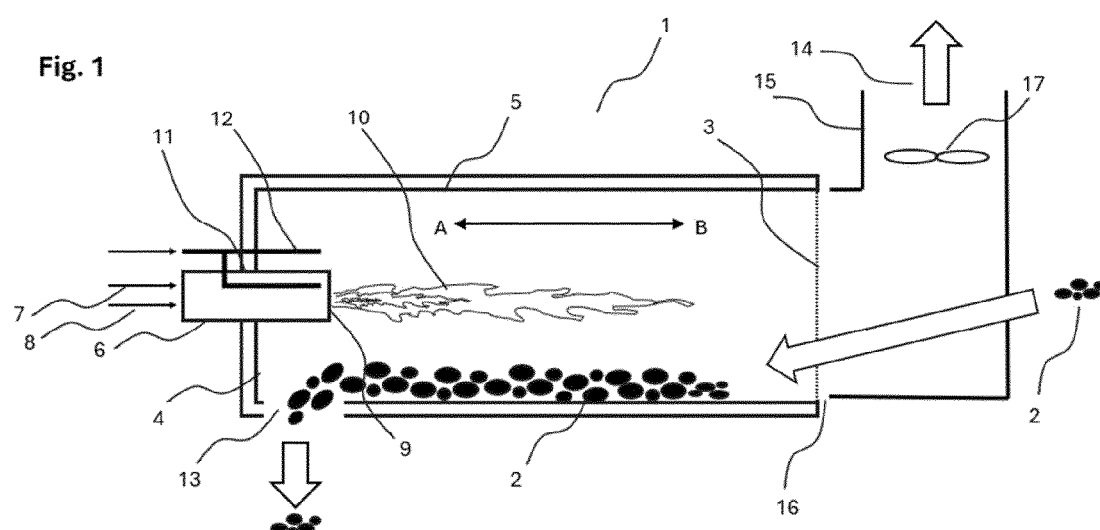
5. The method of any one of the preceding claims, **characterized in that** the furnace is a rotatable furnace, especially a rotatable kiln. 5
6. The method of any one of the preceding claims, **characterized in that** the material to be processed is a solid material or comprises a solid material. 10
7. The method of claim 6, **characterized in that** limestone is processed in said furnace.
8. The method of any one of the preceding claims, **characterized in that** the distance between the first lance and the center of the burner outlet is less than 1.2 times the radius of the burner outlet, , less than the radius of the burner outlet or less than 0.5 times the radius of the burner outlet. 15 20
9. The method of any one of the preceding claims, **characterized in that** the distance between the second lance and the center of the burner outlet is more than 2 times or more than 3 times the radius of the burner outlet. 25
10. The method of any one of the preceding claims, **characterized in that** said fuel is a solid fuel or comprises a solid fuel such as wood powder. 30
11. The method of any one of the preceding claims, **characterized in that** a process parameter of the main combustion reaction is determined and that the flow of the first gaseous stream and the flow of the second gas stream are adjusted depending on the process parameter. 35
12. The method of any one of the preceding claims, **characterized in that** the total flowrate of the first gas stream and of the second gas stream is kept constant. 40
13. The method of any one of the preceding claims, **characterized in that** one or more first gaseous streams and one or more second gaseous streams are injected into the kiln and that the total flowrate of oxygen supplied via the first gaseous streams and via the second gaseous streams is between 10 vol-% and 40 vol-% of the total oxygen required for a stoichiometric combustion of the fuel supplied to the furnace. 45 50
14. The method of any one of the preceding claims, **characterized in that** the velocity of the first gaseous stream is selected such that it starts to coalesce with the fuel at a distance of at least half of the burner diameter. 55

15. Furnace for carrying out a method according to one of the preceding claims, **characterized in that** the furnace is enclosed by a front side, a backwall and one or more lateral walls, wherein a burner is provided in said backwall of the furnace, wherein a first lance for providing a first gaseous stream having an oxygen content of at least 80 % by volume is provided in said backwall,

wherein a second lance for providing a second gaseous stream having an oxygen content of at least 80 % by volume is provided in said backwall,

wherein the distance between the first lance and the center of the burner outlet is less than 1.5 times the radius of the burner outlet, and wherein the distance between the second lance and the center of the burner outlet is more than 1.5 times the radius of the burner outlet

and wherein the distance between the second lance and the lateral walls of the furnace is more than 20% of the diagonal of said back-wall of the furnace.





EUROPEAN SEARCH REPORT

Application Number

EP 25 17 0536

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 572 938 A (LEGER CHRISTOPHER B [US]) 12 November 1996 (1996-11-12)	15	INV. F23G5/12
Y	* column 3, line 42 - column 5, line 58 * * figures 1,2 *	1-14	F23G5/20 F23L7/00
Y	----- US 8 137 099 B2 (PENFORNIS ERWIN [FR]; HAMMEL MAGUELONNE [FR] ET AL.) 20 March 2012 (2012-03-20) * column 5, line 19 - line 25 * * column 6, line 57 - column 7, line 3 * * figures 2,2A * -----	1-14	
			TECHNICAL FIELDS SEARCHED (IPC)
			F23G F23L F23C
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		11 September 2025	Gavriliu, Costin
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P24C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 25 17 0536

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-09-2025

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5572938 A	12-11-1996	BR 9600380 A	03-03-1998
		CA 2169318 A1	14-08-1996
		EP 0726437 A1	14-08-1996
		KR 960031370 A	17-09-1996
		US 5572938 A	12-11-1996

US 8137099 B2	20-03-2012	AT E450766 T1	15-12-2009
		BR PI0614255 A2	15-03-2011
		CN 101233377 A	30-07-2008
		EP 1913321 A1	23-04-2008
		ES 2337401 T3	23-04-2010
		FR 2889579 A1	09-02-2007
		JP 5074395 B2	14-11-2012
		JP 2009503430 A	29-01-2009
		US 2009130615 A1	21-05-2009
		WO 2007015029 A1	08-02-2007

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82