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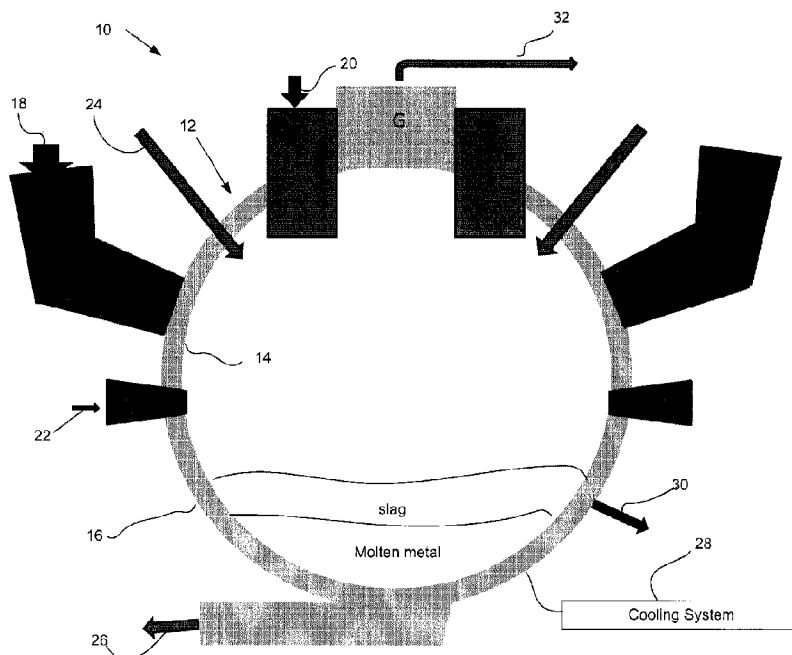
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(54) Titre : APPAREIL DE FUSION ET SON PROCEDE D'UTILISATION
(54) Title: SMELTING APPARATUS AND METHOD OF USING THE SAME



(57) Abrégé/Abstract:

The present document describes a smelting apparatus for smelting metallic ore. The smelting apparatus comprises a furnace having a continuous curved wall and end walls defining a longitudinal volume having a longitudinal axis in a horizontal direction. The continuous curved wall has a lowermost area. The longitudinal volume is divided in at least three longitudinal layers comprising a top layer within which gasified fuel is combusted for creating a hot gas composition at a temperature sufficient to release, from the metallic ore, at least molten metal and slag, a lowermost layer at the lowermost area for holding molten metal, and a mid layer above the lowermost layer in which the slag accumulates.

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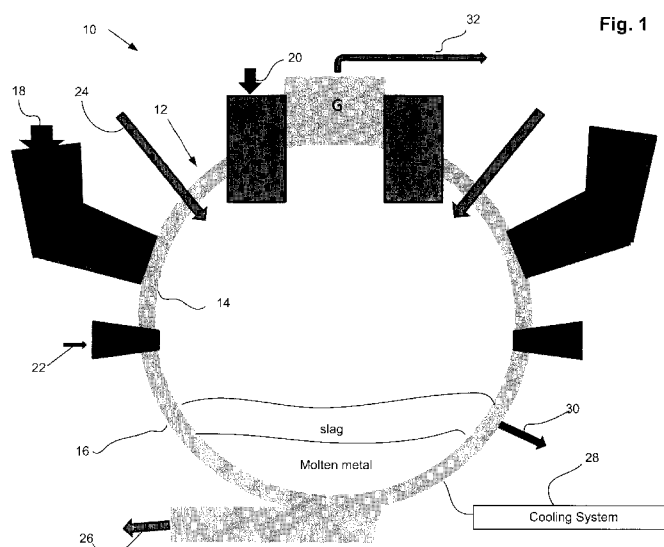
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(54) Title: SMELTING APPARATUS AND METHOD OF USING THE SAME



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SMELTING APPARATUS AND METHOD OF USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

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BACKGROUND

(a) Field

[0002] The subject matter disclosed generally relates to smelting apparatus and to smelting processes. More particularly, the subject matter relates to smelting furnaces for iron ore smelting and processes for smelting iron ore.

(b) Related Prior Art

[0003] Smelting is a form of extractive metallurgy. Its main use is to produce a metal from its ore. This includes production of silver, iron, copper and other base metals from their ores. Smelting uses heat and a chemical reducing agent to decompose the ore, driving off other elements as gasses or slag and leaving just the metal behind. The reducing agent is commonly a source of carbon such as coke, or charcoal. The carbon, or carbon monoxide derived from it, removes oxygen from the ore, leaving behind elemental metal. The carbon is thus oxidized in two stages, producing first carbon monoxide and then carbon dioxide. As most ores are impure, it is often necessary to use flux, such as limestone, to remove the accompanying rock gangue as slag.

[0004] Plants for the electrolytic reduction of aluminum are also generally referred to as smelters. These do not melt aluminum oxide but instead dissolve it in aluminum fluoride. They normally use carbon electrodes, but novel smelter designs use electrodes that are not consumed in the process. The end product is molten aluminum.

[0005] Smelting involves more than just melting the metal out of its ore. Most ores are a chemical compound of the metal with other elements, such as oxygen (i.e., an oxide), sulfur (i.e., a sulfide) or carbon and oxygen together (i.e., a carbonate). To produce the metal, these compounds have to undergo a chemical reaction. Smelting therefore consists of using suitable reducing substances that will combine with those oxidizing elements to free the metal.

[0006] Current smelting furnace designs are more than often either tall vertical cylinders or rectangular boxes. Both result in either high construction costs for the tall cylindrical approach or on-going operational, and maintenance refractory costs for rectangular box designs (refractory is not stable in box type designs).

[0007] Numerous types of furnaces exist on the market. In an example, US patent no. 6,537,342 describes an apparatus for a metal reduction and melting process, in which a metal and carbon-containing burden is heated in an induction furnace including a heating vessel in which the burden can float in at least one heap on a liquid metal bath in the vessel. The apparatus is characterized in that it includes at least one induction heater or inductor located at the bottom center line of the vessel, with the longitudinal access oriented perpendicular to the access of the vessel. The furnace is electrically heated from the outside (via induction means).

[0008] Even if US patent no. 6,537,342 provides a cylindrical design to its furnace, it leads to an inefficient way of providing heat to the furnace (i.e., heat needs to travel towards the wall of the furnace as well as through the refractory material before heating the interior of the furnace).

[0009] In another example, US patent no. 6,146,437 describes a metal containing compound reduction and melting process which entails feeding a burden made of a mixture of the metal containing compound and a suitable reductant in particulate form into an electrically heatable vessel which contains a

bath of the metal in liquid form so that a reaction zone is formed in the burden in which the metal containing compound is reduced and a melting zone is formed below the reaction zone in which the reduced metal is melted. The furnace is electrically heated from the outside (via electrical means).

[0010] Even if US patent no. 6,146,437 provides a cylindrical design to its furnace, it leads to an inefficient way of providing heat to the furnace (i.e., heat needs to travel towards the wall of the furnace as well as through the refractory material before heating the interior of the furnace). Use of electrical heating is both costly and inefficient.

[0011] In another example, US patent no. 5,411,570 describes a method of making steel, by heating in a channel type induction furnace an iron containing burden and carbon, the carbon being included in the burden and/or contained in hot metal, and maintaining the temperature of the liquid product so formed above its liquidus temperature by controlling the amount of heat supplied to the furnace and/or the rate at which the burden is added to the furnace.

[0012] Even if US patent no. 5,411,570 provides a cylindrical design to its furnace, it leads to an inefficient way of providing heat to the furnace (i.e., heat needs to travel towards the wall of the furnace as well as through the refractory material before heating the interior of the furnace).

[0013] There is therefore a need for an improved smelting apparatus and for a method of operating the same.

SUMMARY

[0014] According to an embodiment, there is provided a smelting apparatus for smelting metallic ore, the smelting apparatus comprising a furnace having a continuous curved wall and end walls defining a longitudinal volume having a longitudinal axis in a horizontal direction, the continuous curved wall having a lowermost area, wherein the longitudinal volume is divided in at least three longitudinal layers comprising a top layer within which gasified fuel is

combusted for creating a hot gas composition at a temperature sufficient to release, from the metallic ore, at least molten metal and slag, a lowermost layer at the lowermost area for holding molten metal, and a mid layer above the lowermost layer in which the slag accumulates.

[0015] According to an aspect, the continuous curved wall forms a cylinder.

[0016] According to an aspect, the continuous curved wall forms an edgeless curve.

[0017] According to an aspect, the apparatus further comprises a raw material inlet within the continuous curved wall in fluid communication with the top layer for supplying the metallic ore to the furnace.

[0018] According to an aspect, the apparatus further comprises a combustion air inlet within the continuous curved wall in fluid communication with the top layer for providing air for inducing combustion in the furnace.

[0019] According to an aspect, the apparatus further comprises a molten metal outlet in the lowermost area of the continuous curved wall in fluid communication with the lowermost layer for allowing molten metal to exit the furnace continuously and selectively.

[0020] According to an aspect, byproduct gases are released from the metallic ore and hot gas composition, and further wherein the continuous curved wall comprises an uppermost area which comprises a byproduct hot gas outlet fluidly connected to the furnace providing an exit from the furnace for the byproduct gases.

[0021] According to an aspect, the apparatus further comprises a fuel inlet within the continuous curved wall in fluid communication with the top layer for supplying a fuel to the furnace and a hot gas inlet within the continuous curved

wall in fluid communication with the top layer for supplying a hot gas to the furnace for gasifying the fuel and thereby producing the gasified fuel.

[0022] According to an aspect, the apparatus further comprises a hot gas generator for providing gasified fuel and a gasified fuel inlet within the continuous curved wall in fluid communication with the top layer for supplying gasified fuel to the furnace.

[0023] According to an aspect, the furnace comprises an interior surface, the interior surface being lined with a refractory material.

[0024] According to an aspect, the apparatus further comprises a cooling system operatively connected to the furnace for cooling an exterior surface of the furnace.

[0025] According to an embodiment, there is provided a method for smelting a metallic ore comprising within a furnace having a continuous curved wall and end walls defining a longitudinal volume having a longitudinal axis in a horizontal direction, combusting a gasified fuel for creating a hot gas composition at a temperature to release, from the metallic ore a molten metal.

[0026] According to an aspect, the apparatus further comprises further comprising charging a raw material to the furnace prior oxidizing the gasified fuel.

[0027] According to an aspect, the apparatus further comprises supplying a fuel to the furnace; and supplying a hot gas to the furnace for gasifying the fuel prior combusting the gasified fuel.

[0028] According to an aspect, the apparatus further comprises supplying gasified fuel to the furnace.

[0029] According to an aspect, the apparatus further comprises cooling an exterior surface of the furnace.

[0030] According to an embodiment, there is provided a smelting apparatus for smelting metallic ores, the smelting apparatus comprising: a

horizontally oriented cylindrical furnace; a raw material inlet operatively connected to the furnace for providing a raw material in the furnace at least one of: a fuel inlet operatively connected to the furnace for providing a fuel in the furnace and a hot gas inlet operatively connected to the furnace for providing a hot gas in the furnace for gasifying the fuel, the gasified fuel for reacting with the raw material; and a hot gas generator for reacting with the raw material; a combustion air inlet operatively connected to the furnace for providing combustion air in the furnace; and a molten metal outlet operatively connected to the furnace for allowing molten metal to continuously exit the furnace; wherein when in operation, the fuel is gasified to create a hot fuel gas that is combusted by the combustion air, thereby creating a hot gas composition and a temperature to release the molten metal from its ore and to smelt the metallic ores.

[0031] According to another embodiment, the furnace comprises an interior surface, the interior surface being refractory lined.

[0032] According to a further embodiment, at least one of the fuel inlet, the hot gas inlet, the combustion air inlet, the hot gas generator and the molten metal outlet respectively comprises a plurality of fuel inlets, a plurality of hot gas inlets, a plurality of combustion air inlets, a plurality of hot gas generator and a plurality of molten metal outlets as a function of overall length or diameter of the furnace.

[0033] According to yet another embodiment, the smelting apparatus further comprises a byproduct hot gas outlet operatively connected to the furnace for providing byproduct hot gas to exit the furnace.

[0034] According to another embodiment, the smelting apparatus further comprises a cooling system operatively connected to the furnace for cooling an exterior surface of the furnace.

[0035] According to a further embodiment, the furnace defines an interior diameter and further wherein the interior diameter varies from about 3 meters to about 6 meters.

[0036] According to another embodiment, the furnace defines a length and further wherein the length varies from about 6 meters to about 30 meters.

[0037] According to yet another embodiment, the fuel comprises a lump carbonaceous fuel.

[0038] According to another embodiment, the lump carbonaceous fuel comprises at least one of: coal, petcoke, coke and biomass carbon.

[0039] According to a further embodiment, the hot gas comprises natural gas.

[0040] According to yet another embodiment, the raw material comprises iron ore.

[0041] According to another embodiment, there is provided a method for smelting a metallic ore comprising: within a horizontally oriented cylindrical furnace, oxidizing a gasified hot fuel for creating a hot gas composition and a temperature to release a molten metal from its ore and to smelt the metallic ore; and continuously providing the molten metal to exit the furnace.

[0042] According to another embodiment, the method further comprises: charging a fuel to the furnace; and charging a hot gas to the furnace for gasifying the fuel prior oxidizing the gasified hot fuel.

[0043] According to a further embodiment, charging the fuel to the furnace comprises continuously charging the fuel to the furnace and charging the hot gas to the furnace comprises continuously charging the hot gas to the furnace.

[0044] According to yet another embodiment, the method further comprises charging a raw material to the furnace prior oxidizing the gasified hot fuel.

[0045] According to another embodiment, the method further comprises cooling an exterior surface of the furnace.

[0046] According to a further embodiment, the method further comprises providing an interior surface of the furnace with a refractory material.

[0047] According to yet another embodiment, the method further comprises providing byproduct hot gas to exit the furnace while at least one of: gasifying the fuel and oxidizing a gasified hot fuel.

[0048] According to another embodiment, the metallic ore is an iron ore.

[0049] Features and advantages of the subject matter hereof will become more apparent in light of the following detailed description of selected embodiments, as illustrated in the accompanying figures. As will be realized, the subject matter disclosed and claimed is capable of modifications in various respects, all without departing from the scope of the claims. Accordingly, the drawings and the description are to be regarded as illustrative in nature, and not as restrictive and the full scope of the subject matter is set forth in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] Further features and advantages of the present disclosure will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0051] Fig. 1 is a front elevation cross-sectional view of a smelting apparatus in accordance with an embodiment; and

[0052] Fig. 2 is a front elevation cross-sectional view of a smelting apparatus in accordance with another embodiment.

[0053] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION

[0054] In embodiments there are disclosed smelting apparatus and methods of operating the same.

[0055] Referring now to Fig. 1 and according to an embodiment, there is shown a smelting apparatus **10**. The smelting apparatus **10** is for smelting metallic ores. The smelting apparatus **10** includes a horizontally oriented cylindrical furnace **12** which has an interior surface **14** and an exterior surface **16**. The smelting apparatus **10** further includes a fuel inlet **18** which is operatively connected to the furnace **12** for providing a fuel in the furnace **12**. According to an embodiment, the fuel includes, without limitation, coal, petcoke, coke, biomass carbon (i.e., either powder or briquetted), and the like.

[0056] The smelting apparatus **10** further includes a raw material inlet **20** which is operatively connected to the furnace **12** for providing a raw material in the furnace **12**. According to an embodiment, the raw material includes, without limitation, any fine ore which meets the overall economic requirements and additional flux materials as required for the chemical balance of the process (process reactions described below). More specifically, the raw material may be fine iron ore which meets the overall economic requirements and additional flux materials as required for the chemical balance of the process which is involved within the furnace **12**.

[0057] The smelting apparatus **10** further includes a hot gas inlet **22** which is operatively connected to the furnace **12** for providing a hot gas in the furnace **12**. It is to be mentioned that while any hydrocarbon gas can be used, natural gas is an economically viable choice. The smelting apparatus **10** further includes a combustion air inlet **24** which is operatively connected to the furnace **12** for providing air inducing combustion in the furnace **12**. It is to be mentioned that, while the furnace **12** is in operation, combustion from combustion air entering the furnace **12** via combustion air inlet **24**, is not complete to provide oxidation in the second step of the chemical reaction.

[0058] The purpose of the oxidation is to produce a mix of primarily CO and some CO₂ which will react with the ore thereby removing oxygen from the

ore, reducing the ore to the metallic form and shifting the gas composition to primarily CO₂.

[0059] It is to be mentioned that the amount of heat needed for the smelting process involved within the furnace **12** is internally provided within the furnace **12**.

[0060] The smelting apparatus **10** further includes a metal outlet **26** which is operatively connected to the furnace **12** for the metal to exit (i.e., continuously exit) the furnace **12**. The smelting apparatus **10** may further include a slag outlet **30** which is operatively connected to the furnace **12** for slag to exit (i.e., periodically exit) the furnace **12**. The slag is made from the non-metallic elements in the ore and the fluxes added with the raw material charge to assure that the slag is molten at the furnace operating temperature.

[0061] Additionally, according to an embodiment, the smelting apparatus **10** further includes a byproduct hot gas outlet **32** operatively connected to the furnace **12** for the byproduct hot gas to exit the furnace **12**. After the various chemical reactions are completed within the furnace **12** and the ore is reduced to metal, the byproduct hot gas is a combination of CO, CO₂ and N₂ (in the case when natural gas is the fuel).

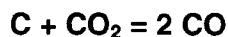
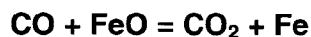
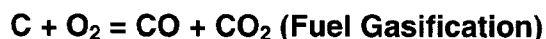
[0062] According to another embodiment, the interior surface **14** is refractory lined. The refractory material used for the interior surface **14** may include, without limitation, various carbon based materials and Al₂O₃ based materials.

[0063] According to another embodiment, the refractory materials used will vary depending on their location within the furnace **12** as a function of process temperature and location. For example, various carbon based materials may be used in the lower portion of the furnace **12**, while Al₂O₃ based materials may be used in the upper portion of the furnace **12**. Both preformed fired bricks and castable materials may be used as a function of location and economics.

[0064] According to another embodiment, the smelting apparatus **10** may further include a cooling system **28** which may be operatively connected to the furnace **12** for cooling the exterior surface **16** of the furnace **12**. The furnace **12** may be cooled with water based on economics. Water may be recirculated through a common heat exchanger and reused as the cooling agent or fluid.

[0065] According to an embodiment, there is provided a smelting apparatus **10** for smelting metallic ore. The smelting apparatus **10** comprises a furnace **12** having a continuous curved wall **15** and end walls (not shown) defining a longitudinal volume having a longitudinal axis in a horizontal direction. The continuous curved wall **15** has a lowermost area **17**. The longitudinal volume is divided in at least three longitudinal layers comprising a top layer (A) within which gasified fuel is combusted for creating a hot gas composition at a temperature sufficient to release, from the metallic ore, at least molten metal and slag, a lowermost layer (C) at the lowermost area for holding molten metal, and a mid layer (B) above the lowermost layer in which the slag accumulates.

[0066] In operation, within the furnace **12**, the fuel is gasified to create a hot fuel gas that is combusted by the combustion air creating a hot gas composition and a temperature to smelt the metallic ores. For iron ores, these chemical reactions occurring within the furnace **12** result in the following chemical formulas:



[0067] It is to be noted that similar reactions may occur within the furnace **12** for other metallic elements that are in the ore (other than iron).

[0068] The smelting apparatus **10** as described above utilizes a horizontally oriented cylindrical furnace **12** defining a horizontal axis which

combines the low height approach of the box concept with the inherent refractory stability of the cylindrical approach.

[0069] According to another embodiment, the smelting apparatus **10** may be used to process mine and steel mill waste products.

[0070] According to a further embodiment, the smelting apparatus **10** may be used with a broad range of carbon sources. As mentioned above, carbon sources may include, without limitation, coal, charcoal, coke, petcoke, and biomass (i.e., sawdust), and the like.

[0071] According to yet another embodiment, the smelting apparatus **10** may be used for other metals, such as, without limitation, silver, copper and other base metals from their ores.

[0072] The smelting apparatus **10** has a horizontally oriented cylindrical furnace **12**. The system capacity operating the smelting apparatus **10** may be expanded readily by making the furnace **12** longer. Both diameter and length may be variable. As such, doubling the length would double the production rate and doubling the diameter would quadruple the production rate.

[0073] According to an embodiment, the interior diameter of the furnace **12** may vary from about 3 meters to about 6 meters and the length of the furnace **12** may vary from about 6 meters to about 30 meters, as a function of a desired production capacity. For example, the capacity of the smelting apparatus may be about 1,500 tons or more of molten metal per day.

[0074] The smelting apparatus **10** may further include, without limitation, hot air delivery options, tuyeres (i.e., ceramic tuyeres, cast metal water cooled tuyeres and/or uncooled ceramic tuyeres.), continuous casting, raw material charging options and the like (not shown).

[0075] According to another embodiment, the furnace **12** may be filled utilizing a static multi-point raw material charging system to provide the raw material to the raw material inlet **20** and into the furnace **12**.

[0076] The furnace **12** has a low height design which eliminates the requirement for physically strong fuel, such as, without limitation, metallurgical coke. The low height design of furnace **12** also eliminates the requirement for important structural support under the furnace **12**.

[0077] The furnace **12** may have a refractory lining extending from the interior surface **14** which is inherently stable under operating conditions. This configuration allows long furnace life and stable operating conditions.

[0078] Thus, during operation of the smelting apparatus **10**, the fuel is charged to the furnace **12** via the fuel inlet **18**. The fuel may be lump carbonaceous fuel or any other suitable fuel. The fuel may be continuously charged to the furnace **12**. Alternatively, the fuel may also be fed in batch to the furnace **12**. The fuel inlet **18** may be located on the side of the furnace **12**, or at any location at the periphery of the furnace **12** such as to fluidly connect the fuel inlet **18** and the furnace **12**.

[0079] The raw material is charged to the furnace **12** via the raw material inlet **20**. The raw material may be continuously charged to the furnace **12** or charged in a batch operation to the furnace **12**. The raw material may be fed on the top of the furnace **12** via the raw material inlet **20**.

[0080] The hot gas may be injected to the furnace **12** via the hot gas inlet **22**. The hot gas may be, without limitation, hot blast air. The hot gas may be injected via the hot gas inlet **22** below the carbonaceous fuel inlet **18**, or at any location at the periphery of the furnace **12**.

[0081] Combustion air is injected to the furnace **12** via the combustion air inlet **24**. The combustion air may be post combustion air and may be injected to the furnace **12**, without limitation, at the base of the raw material inlet **20**.

[0082] The carbonaceous fuel is then gasified in an oxygen lean environment to create a hot fuel gas that is combusted by the post combustion air creating the necessary hot gas composition and temperature to smelt the ore feed.

[0083] The smelted ore descends to the base of the furnace **12** where the metal will separate from the non-metallic components (i.e., slag). The metal is cast (or continuously cast) from the metal outlet(s) **26** of the furnace **12**. It is to be noted that the metal outlet **26** may be located at the bottom portion of the furnace **12**. Only a few inches of molten metal need to be left in the bottom portion of the furnace **12** to prevent gas communication from the bottom portion such as to prevent oxygen to enter the furnace **12**.

[0084] The slag may be cast (or periodically cast) from the furnace **12** via the slag outlet(s) **30** by opening a recess on the side of the furnace **12** to allow the slag to exit the furnace **12** or by periodically drilling a hole in the wall of the furnace **12** at the height of the slag (at the mid layer) to enable the slag to exit the furnace **12**. The furnace byproduct gas (N_2 , CO and CO_2) leaves the furnace **12** via the byproduct hot gas outlet(s) **32** to be transferred to environmental treatment and subsequent energy recovery. It is to be mentioned that the byproduct hot gas may be, without limitation, reused within the hot gas (or hot blast), sold as a fuel, used/sold to heat a boiler to produce electricity, and the like (depending on the geographical location).

[0085] According to another embodiment and referring now to Fig. 2, the furnace **12** may include gas burner(s) or hot gas generator(s) which is connected to a gasified fuel inlet **34** that will replace the use of the carbonaceous fuel inlet **18** and of the hot gas inlet **22** (i.e., the use of solid fuel and hot air blast). The hot products of combustion may provide the necessary thermal energy to assure molten products, metal and slag, at the outlets **26**, **30** of the furnace **12**. The primary charge material, self-reducing briquettes may be adjusted in their overall chemistry to offset any changes in the overall furnace chemical balance.

[0086] According to another embodiment, it is to be noted that all inlets and outlets **18, 20, 22, 24, 26, 30, 32** of the furnace **12** may include a plurality of inlets/outlets as a function of the overall length and/or diameter of the furnace **12**.

[0087] One of the advantages of the smelting apparatus **10** as described above is the horizontal orientation of the cylindrical design, which utilizes the pressure containment advantages of the cylindrical approach (vertically oriented cylindrical approach) without the cost disadvantages of high construction, while avoiding the refractory instability associated with the rectangular approach (horizontally oriented rectangular approach). According to the configuration of the smelting apparatus **10** as described above, no induction/electrical heating (i.e., which is costly and less efficient) is employed for providing heat to the interior of the furnace **12**, all the heat required for the process is generated from the carbon (i.e., lump carbonaceous fuel) charged to the furnace **12**. Furthermore, the furnace **12** is fixed; i.e., it does not rotate.

[0088] According to the configuration of the smelting apparatus **10**, there is no accumulation of the molten metal in the furnace **12** and the process is not dependent on this accumulation. All metal produced is continuously cast from the furnace **12**.

[0089] While preferred embodiments have been described above and illustrated in the accompanying drawings, it will be evident to those skilled in the art that modifications may be made without departing from this disclosure. Such modifications are considered as possible variants comprised in the scope of the disclosure.

CLAIMS:

1. A smelting apparatus for smelting metallic ore, the smelting apparatus comprising a furnace having a continuous curved wall and end walls defining a longitudinal volume having a longitudinal axis in a horizontal direction, the continuous curved wall having a lowermost area, wherein the longitudinal volume is divided in at least three longitudinal layers comprising a top layer within which the metallic ore is decomposed using a reducing agent to release, from the metallic ore, at least molten metal and slag, a lowermost layer at the lowermost area for holding molten metal, and a mid layer above the lowermost layer in which the slag accumulates.
2. The smelting apparatus of claim 1, wherein the reducing agent comprises gasified fuel.
3. The smelting apparatus of claim 1, wherein the continuous curved wall forms a cylinder.
4. The smelting apparatus of claim 1, wherein the continuous curved wall forms an edgeless curve.
5. The smelting apparatus of claim 1, further comprising a raw material inlet within the continuous curved wall in fluid communication with the top layer for supplying the metallic ore to the furnace.
6. The smelting apparatus of claim 4, further comprising an air inlet within the continuous curved wall in fluid communication with the top layer for providing air for inducing combustion in the furnace.

7. The smelting apparatus of claim 5, further comprising a molten metal outlet in the lowermost area of the continuous curved wall in fluid communication with the lowermost layer for allowing molten metal to exit the furnace continuously and selectively.

8. The smelting apparatus of claim 6, wherein byproduct gases are released from the metallic ore and hot gas composition, and further wherein the continuous curved wall comprises an uppermost area which comprises a byproduct hot gas outlet fluidly connected to the furnace providing an exit from the furnace for the byproduct gases.

9. The smelting apparatus of claim 2, further comprising a fuel inlet within the continuous curved wall in fluid communication with the top layer for supplying a fuel to the furnace and a hot gas inlet within the continuous curved wall in fluid communication with the top layer for supplying a hot gas to the furnace for gasifying the fuel and thereby producing the reducing agent.

10. The smelting apparatus of claim 7, further comprising a hot gas generator for providing gasified fuel and a gasified fuel inlet within the continuous curved wall in fluid communication with the top layer for supplying gasified fuel to the furnace.

11. The smelting apparatus of claim 1, wherein the furnace comprises an interior surface, the interior surface being lined with a refractory material.

12. The smelting apparatus of claim 1, further comprising a cooling system operatively connected to the furnace for cooling an exterior surface of the furnace.

13. A method for smelting a metallic ore comprising:

- within a furnace having a continuous curved wall and end walls defining a longitudinal volume having a longitudinal axis in a horizontal direction, decomposing the metallic ore using a reducing agent to release, from the metallic ore a molten metal.

14. The method of claim 13, further comprising charging a raw material to the furnace prior to oxidizing the reducing agent.

15. The method of claim 13, further comprising:

- supplying a fuel to the furnace; and
- supplying a hot gas to the furnace for gasifying the fuel.

16. The method of claim 13, further comprising supplying gasified fuel to the furnace.

17. The method of claim 13, further comprising cooling an exterior surface of the furnace.

