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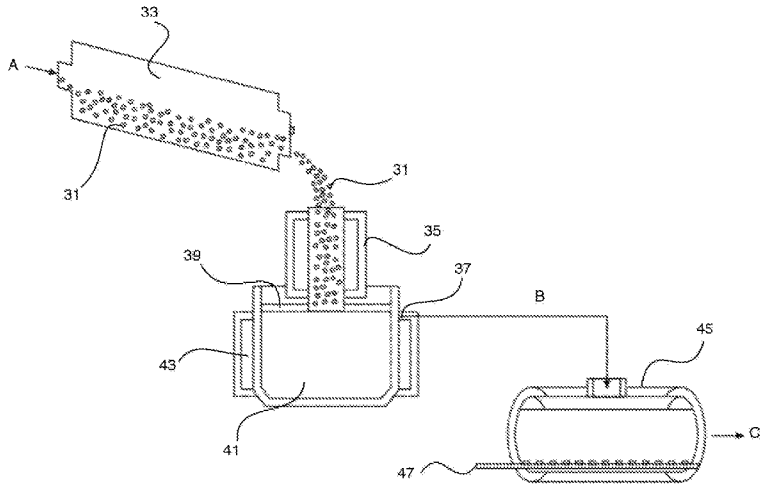


FIGURE 7

(57) Abstract: A process for producing and reducing an iron ore briquette, the process comprising the steps of: a. combining together a comminuted iron bearing material, a comminuted carbonaceous material, a fluxing material and a primary binder material to form a briquette mixture; b. adding a metallic particulate material to the briquette mixture; c. adding hot water and a secondary binder material to the briquette mixture; d. kneading the briquette mixture together; e. compacting the briquette mixture under pressure to form a green briquette, f. subjecting the green briquette to a primary curing to form a stable iron ore briquette or pre-heating the green briquette by conventional or induction heating means up to a temperature of 800°C; and g. feeding the green briquette or pre-heated green briquette to a furnace to produce pig iron, wherein when the iron ore briquette is subjected to electromagnetic radiation, the metallic particulate material dispersed within the iron ore briquette promotes formation of increased reactivity or seed sites and thereby increase the reduction of the iron ore briquette to form pig iron.

WO 2014/190391 A1

A PROCESS FOR PRODUCING AND REDUCING AN IRON OXIDE BRIQUETTE

TECHNICAL FIELD

[001] The present invention relates to a process for the manufacture of a complete iron oxide carbon briquette, with the flux and binding agents to be used either as feed to a blast furnace or for reduction and melting in an electric arc or induction furnace to produce pig iron.

BACKGROUND ART

[002] The vast majority of steel is manufactured via a blast furnace. In the simplest form, coking coal is processed in the coke ovens to produce coke. Lump iron ore, hematite and coke are fed into the blast furnace, where pig iron is then produced. In 2012, the world production of steel was approximately 1,500 million tons, with approximately 700 million tons produced in China.

[003] The practice of steel manufacturing in China requires approximately 2.6 tons of coking coal for the manufacture 1 ton of steel. Current steel manufacturing processes are becoming problematic wherein the price of coking coal is increasing. During the global financial crisis, the price of coking coal has gone up as high as US$350 per ton, consequently pushing the price of steel to unprecedented heights. Another major concern is that some steel companies are predicting that there will not be enough coking coal to supply the blast furnace in 30 years.

[004] Accordingly, the production of steel from low-grade iron ore or scrap materials has increased significantly as the availability and supply of high-grade iron ore and coking coal becomes limited and too expensive. Subsequently, various methods have been developed and employed in an attempt to achieve lower cost steel production.

[005] Specific market niches have developed such that melted reduced iron ore briquettes have a good market in Asia, as feed to the electric furnace steel industry within the region. A recent example is BHP Billiton attempting to supply the Asian market by

establishing a hot briquette iron plant in Western Australia. Similarly, the Hismelt ("High intensity smelting") process established by Rio Tinto, attempts to produce iron via a direct reduction of iron ore by coal.

[006] Increased efficiency in blast furnace operations has been achieved through the use of pelletized ores, wherein the uniform grain size assists to increase permeability in the furnace. For example, in the undated article entitled "*Self reduced iron ore pellets using flexicoke as reductant*" by M. Specht, C. Seaton and A. Morales of Simon Bolivar University of Caracas, Venezuela, the authors describe their work on using flexicoke produced from the heavy crude oil refining as a reductant mixed with iron ore in a pellet. Flexicoke, up to 17% weight, and binding materials tested are Portland cement, lime, a cellulose binder called Peridur and clay. The cement pellets showed great strength of 320 kg/pellet but this was reduced by 82% after reduction with cracking and peeling of surfaces. The reduced pellets with cement showed an internal structure of interconnected pores giving a sponge-like structure. On the other hand, self-reduced pellets with lime increased 214% in mechanical strength after reduction to 40kg/pellet. However, this is insufficient to meet the blast furnace requirement of 60 kg/pellet. Additionally, pellets of 10 mm in diameter were prepared in this case rather than briquettes.

[007] US Patent 20070157761 entitled "*Use of an Induction furnace for the production of iron from iron ore*" describes a process utilizing an induction furnace to reduce and melt iron ore to pig iron. The accompanying representations illustrate the reduction-melting zone to be approximately the same diameter as the reservoir for the slag and molten pig iron. However, the large diameter of the reduction-melting zone means that the electromagnetic energy may not reach the charge completely and could lead to unreduced iron ore reaching the reservoir and reporting to the slag.

[008] The frequency of the electromagnetic energy is important in induction heating and reduction of iron oxide. For example of experimentation with electromagnetic energy frequency has been conducted by K. Hara and M. Hayashi of the Tokyo Institute of Technology, M. Sato of the National Institute of Fusion Science and K. Nagata of Tokyo University, wherein a 12.5 kW by 2.45 GHz reactor was used on mixed

powders of magnetite and carbon. It took 40 minutes to reach 1200C and at 1400C, additional iron ore and carbon were added to produce molten pig iron. The applicant has experimented with 2.45 GHz and 981 kHz in the reduction of iron oxide with carbon. However, the resulting process was time consuming wherein a prolonged period of time was required for the mass to reach a high temperature for reduction and melting. Accordingly, the applicant has applied modifications in respect of the frequency of electromagnetic energy, which are described later in this application.

[009] In addition to the problematic commercial issues such as the availability and cost of supplies, current steel making processes also produce a significant amount of greenhouse gas emissions, starting from the coking oven operations. The 5th Inter-governmental Panel on Climate Change (IPCC) recommended that carbon emissions much be reduced by 40% to 70% by 2050 and zero carbon emissions by 2100. Should the carbon emissions not be reduced this would have detrimental environmental effects on climate change.

[010] Accordingly, it is an object of the present invention to provide a process of manufacture of an improved and cost effective iron oxide briquette for use in either a blast or an electric arc or induction furnace for the manufacture of pig iron thereafter. Additionally, a further object of the present invention is to provide an environmentally sustainable process of producing steel.

SUMMARY OF THE INVENTION

[011] According to the present invention, although this should not be seen as limiting the invention in any way, there is proposed a process for producing and reducing an iron ore briquette, the process comprising the steps of:

a. combining together a comminuted iron bearing material, a comminuted carbonaceous material, a fluxing material and a primary binder material to form a briquette mixture;

b. adding a metallic particulate material to the briquette mixture;

c. adding hot water and a secondary binder material to the briquette mixture;

d. kneading the briquette mixture together;

e. compacting the briquette mixture under pressure to form a green briquette,

f. subjecting the green briquette to a primary curing to form a stable iron ore briquette or pre-heating the green briquette up to a temperature of 800°C; and

g. feeding the green briquette or pre-heated green briquette to a furnace to produce pig iron,

wherein when the iron ore briquette is subjected to electromagnetic radiation, the metallic particulate material dispersed within the iron ore briquette promotes formation of increased reactivity sites and thereby increase the reduction of the iron ore briquette to form pig iron.

[012] Preferably, the metallic particulate material is 1 to 10% by weight of total weight of the comminuted iron oxide and the comminuted carbonaceous material of the briquette mixture.

[013] Preferably, the metallic particulate material comprises of very fine ferrous filings.

[014] Preferably, the comminuted iron bearing material is selected from a group consisting of hematite, magnetite, taconite, limonite, siderite, pyrites, chromite and mixtures thereof.

[015] Preferably, the comminuted carbonaceous material is selected from a group consisting of coke, lignite, sub-bituminous coal, bituminous coal, anthracite, graphite, and mixtures thereof.

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[016] Preferably, the comminuted carbonaceous material in the briquette mixture being in excess of 20% of the stoichiometric ratio required for reduction the iron oxide material.

[017] Preferably, the fluxing material is 2 to 8% by weight of total weight of the comminuted iron bearing material and the comminuted carbonaceous material of the briquette mixture.

[018] Preferably, the fluxing material is selected from a group consisting of cement, lime, silica, alumina and mixtures thereof.

[019] Preferably, the primary binder material is selected from a group consisting of borax, soda ash and mixtures thereof.

[020] Preferably, the borax is 2 to 8% by weight of total weight of the comminuted iron bearing material and the comminuted carbonaceous material of the briquette mixture.

[021] Preferably, the soda ash is 1 to 10% by weight of total weight of the comminuted iron bearing material and the comminuted carbonaceous material of the briquette mixture.

[022] Preferably, the secondary binder material comprises of an aqueous sodium silicate solution.

[023] Preferably, the primary curing comprises of drying and aging the green briquette at an ambient temperature for up to 7 days.

[024] Preferably, pre-heating of the green briquette occurs via heating in a conventional heating means or induction heating means.

[025] Preferably, the conventional heating means comprises a rotary kiln.

[026] Preferably, the electromagnetic radiation applied to the iron ore briquette is between 100 to 500 kHz.

[027] Preferably, the electromagnetic radiation is applied via an induction furnace.

[028] Preferably, the iron ore briquette is used as feedstock in an electric arc or induction furnace in the production of pig iron.

[029] Preferably, the iron ore briquette is used as feedstock for a blast furnace in the production of pig iron.

EXPERIMENTAL WORK

[030] Preparation of the iron bearing material

Experimentation was carried out on hematite ore purchased from a chemical supplier, wherein the purchased hematite ore is sufficiently fine and ready for use.

[031] The magnetite concentrate used in the experimentation was derived from a magnetite mine in Western Australia and then subjected to a comminuting process such that the resulting comminuting material being approximately 40 microns in size.

[032] Any known comminuting process known within the art may be applied. For the purposes of the experimentation, the comminuting process was achieved via the application of the intense vortex comminutor as disclosed in Australian Patent Number 2002317626.

[033] Additionally, the comminuted magnetite concentrate may be subjected to a further magnetic separation process, at approximately 5,000 gausses, to achieve a fine and high-grade magnetite concentrate.

[034] Similarly, low-grade hematite ore can be subjected to high intensity magnetic separation, at approximately 10,000 to 14,000 gausses, to achieve a fine and higher-grade hematite ore.

[035] Preparation of the carbonaceous material

Latrobe Valley lignite from Victoria, Australia, was subjected a comminuting process using the intense vortex comminutor. The resulting comminuted lignite being approximately 150 microns in size.

[036] The comminuted lignite was then subjected to a high frequency pulsing microwave of approximately 5.8GHz under vacuum, which heats the lignite up to a temperature of 650°C thereby enabling extraction of a light crude oil and a high carbon residue, the residue serving as the carbonaceous material in the process for producing the iron ore briquette. The residue estimated to comprise of approximately 8% ash content formed of SiO_2, CaO, MgO and Al_2O_3, approximately 6% by weight of volatile hydrocarbons and the remainder being 86% carbon.

[037] Preparation of the iron ore briquette

A test mixture is prepared comprising of the following ingredients:

a. hematite ore- 292 grams
b. lignite residue- 192 grams
c. Portland Cement- 2% to 8% by weight
d. Borax- 2% to 8% by weight
e. Soda Ash- 1% to 5%
f. Iron Fines- 1% to 5%

As an alternative to Portland cement, lime may be used as an appropriate fluxing material. Further, the above mixture can be optimized with further tests utilizing other iron ores.

[038] The mixture is combined and processed utilizing a Sunbeam Blender Model No. PB9800 wherein the mixture is processed for approximately two 10-minute intervals.

[039] Approximately 80 grams of the blended mixture is combined with 4 grams of a sodium silicate solution and 20 grams of hot water. This mixture is kneaded by hand and placed into a briquette mold.

[040] The briquette mold comprises of an inner and outer cylinder, with the inner cylinder having a spherical shaped cavity to produce a spherical shaped briquette. The briquette mold is subjected to compaction wherein the briquette mold is compressed in a Labtech ESSA XRF Powder Press (pressurized up to approximately 40 tons) but for optimal results, the briquette mold is pressurized only to 17.5 tons.

[041] The compacted green briquette is removed from the briquette mold and allowed to age for at least 7 days. The aged green briquettes when subjected to pressure in a press broke at 26 psig.

[042] Reduction and melting of the iron ore briquette

The aged green briquettes are subjected to reduction and melting via an induction furnace. The reduction and melting of the briquettes was carried out in a 10kW – 250Hz medium frequency induction furnace supplied by Furnace Engineering Pty. Ltd.

[043] The briquettes are kept inside a covered carbon crucible adapted to nest within the water-cooled induction coils. A thermocouple located at the outer bottom of the carbon crucible gives an indication of the temperature. Nitrogen gas is fed at the outer bottom of the carbon crucible to minimize oxidation of the carbon crucible and avoid flames.

[044] Preheating of the crucible required about 75 to 80 seconds of full power at 250Hz. Once cooled, the preheated briquette broke at 56 psig.

[045] Melting of the briquette to pig iron requires approximately 4 minutes with a cold crucible.

[046] Upon melting of the preheated hematite briquettes, the partially melted briquette still retained an unreacted and competent core. Similarly, the partially melted magnetite briquette also retained an unreacted and competent core, but unfortunately, the partially melted magnetite briquette the briquette broke while being removed from the

crucible. Nonetheless, both hematite and magnetite briquettes proceeded to reduction and formation of pig iron.

[047] Process of forming pig iron using the iron ore briquette

a. Feeding to a blast furnace

The aged green briquettes need to possess sufficient strength if they are to be used as feedstock for a blast furnace. Accordingly, aged green briquettes are pre-heated in an induction furnace to gain strength to withstand the pressure of the charge in the blast furnace. As feedstock into the blast furnace, the briquettes may be partially or fully cured complete briquettes. Auxiliary coal or gas may be used in the blast furnace operation. The operation of the coke oven is not necessary when using the briquettes formed of the present process thereby removing the pollution from that operation. In the blast furnace, the effective contact between the fine iron ore material and fine carbonaceous material is more efficient and reduces the carbon consumption in the blast furnace. Additionally, the blast furnace operating cost is reduced effectively from the light crude oil produced from the processing of the lignite.

b. Steel making in an Induction furnace

Alternatively, the complete briquettes may be used in an induction furnace. As electricity is more expensive than coal or gas fired heating, the briquettes are pre-heated before being fed into the induction furnace. The aged green briquettes are preheated up to 800C in a gas or coal fired rotary kiln. Once pre-heated, the briquettes are fed into the smaller diameter induction furnace for reduction and melting. The molten pig iron and slag go into the larger reservoir that is heated also by induction, wherein the slag separates to the top while the molten pig iron collects at the lower part. The slag and the molten pig iron are tapped regularly, with the molten pig iron delivered to a converter where oxygen is blown into the converter to produce steel. The molten steel is then molded into ingots or fed into a continuous casting machine.

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BRIEF DESCRIPTION OF THE DRAWINGS

[048] For a better understanding of the present invention and associated method of use, it will now be described with respect to the preferred embodiment which shall be described herein with reference to the accompanying drawings wherein:

[049] Figures 1 is a photograph of a hematite briquette formed according to the process of the present invention;

[050] Figure 2 is a photograph of magnetite briquette formed according to the process of the present invention;

[051] Figures 3A to 3C are photographs depicting a hematite briquette formed according to the process of the present invention and the partial and complete reduction during experimentation;

[052] Figures 4A to 4C are photographs depicting a magnetite briquette formed from according to the process of the present invention and the partial and complete reduction during experimentation;

[053] Figure 5A illustrates a conventional iron ore briquette comprised a mixture of an iron ore material and a carbonaceous material;

[054] Figure 5B illustrates a cross-sectional view of the conventional iron ore briquette and in particular the insufficient reactivity and reduction of the iron ore briquette when subjected to electromagnetic energy;

[055] Figure 6A illustrates a preferred embodiment of an iron ore briquette formed according to the process of the present invention;

[056] Figure 6B illustrates the increased reactivity and reduction of the iron ore briquette formed according to the process of the present invention, when subjected to electromagnetic energy; and

[057] Figure 7 illustrates a preferred embodiment of a process of manufacturing pig iron utilizing iron ore briquettes formed according to the process of the present invention.

DESCRIPTION OF EMBODIMENTS

[058] Figure 1 is a photograph depicting an iron ore briquette 1 formed according to the process of the present invention. In particular, the iron ore briquette 1 pictured is formed from hematite.

[059] Figure 2 is a photograph depicting an iron ore briquette formed according to the process of the present invention. In particular, the iron ore briquette 1 pictured is formed from magnetite.

[060] Whilst the iron ore briquettes 1 depicted are spherical in shape, it is readily appreciated that the iron ore briquettes 1 formed according to the process of the present invention may be of any size, shape and configuration known within the art and appropriate for use.

[061] Figures 3A to 3C are photographs depicting a hematite briquette 3 formed according to the process of the present invention and the partial and complete reduction of the hematite briquette 3 during experimentation.

[062] Figure 3A depicts the complete hematite briquette 3 formed from the process of the present invention. The hematite briquette 3 was subjected to partial reduction and melting via an induction furnace. The result of the partial reduction and melting of the hematite briquette 3 is shown in Figure 3B. Notably, the partially melted hematite briquette 3 still retained an unreacted and competent core. Upon complete reduction and melting in the induction furnace, the hematite briquette 3 formed pig iron 5. Figure 3C illustrates the formation of pig iron 5 from complete melting and reduction of the hematite briquette 3 within a crucible 7 of the induction furnace.

[063] Similarly, Figures 4A to 4C depict a magnetite briquette 9 formed from according to the process of the present invention and the partial and complete reduction during experimentation. Figure 4A shows the complete magnetite briquette 9. Figure 4B illustrates the resulting product when the magnetite briquette 9 was subjected to partial reduction and melting via an induction furnace. The partially melted magnetite briquette 9 also retained an unreacted and competent core. However, as shown in Figure 4B, the partially melted magnetite briquette 9 fragmented upon removal from the crucible. Even so, upon complete melting and reduction, the fragmented magnetite briquette 9 formed pig iron, as shown in Figure 4C. Notably, Figure 4C shows a first melted magnetite briquette 9 on the bottom of the crucible 11, and overlaying the first melted magnetite briquette 9 is a second magnetite briquette 13 which is metalized but not melted.

[064] Referring to Figure 5A there is illustrated a conventional iron ore briquette 15. A conventional iron ore briquette is comprised a mixture of an iron ore material such as Fe_2O_3, and carbon. A conventional briquette 15 such as that illustrated, is then subjected to electromagnetic energy to reduce the iron oxide in the briquette 15 to iron.

[065] Generally speaking, in the reduction of an iron ore briquette to iron, the following reactions occur, in the case of the reduction of hematite below:

$$Fe_2O_3 + C \rightarrow 2FeO + CO$$
$$2FeO + 2C \rightarrow 2Fe + 2CO$$
$$Fe_2O_3 + CO \rightarrow 2FeO + CO_2$$
$$FeO + CO \rightarrow Fe + CO_2$$

[066] Similar reactions occur in reduction of magnetite.

[067] However, although the carbon within a conventional iron ore briquette 15 will reduce iron oxide at temperature, the surface contact must be substantial for effective reduction and to make the process commercially viable.

[068] However, consequently with a conventional iron ore briquette 15 such as that illustrated, the reduction of iron oxide is poor resulting in a substantial amount of unreacted carbon and an unreacted iron core. This is illustrated in Figure 5B wherein a cross-sectional view of the conventional iron ore briquette 15 shows that the reactivity and reduction of the iron ore briquette 15 occurs predominantly on the outer surface of the iron ore briquette 15 which is exposed to the electromagnetic radiation 17. The formation of a layer of wustite 19 around the iron ore briquette 15 prevents the electromagnetic energy from acting on the remaining iron ore briquette 15, consequently leaving a largely unreacted briquette core 21. Accordingly, it can be seen that the reactivity of conventional iron ore briquettes 15 is limited and cannot provide a commercially viable feedstock for the production of steel.

[069] Referring now to Figure 6A, where there is illustrated a preferred embodiment of an iron ore briquette 25 formed according to the process of the present invention. The process of the present invention firstly combines together a comminuted iron bearing material, a comminuted carbonaceous material, a fluxing material and a primary binder material to form a briquette mixture.

[070] The term iron bearing material refers to any material or compound containing iron oxides including but not limited to hematite, magnetite, taconite, limonite, siderite, pyrites, chromite and mixtures thereof. It is readily appreciated that any appropriate iron bearing material known within the art may be utilized. The iron bearing material may be comminuted using any means known within the art. For example, the iron bearing material in the experimentation work was comminuted using the intense vortex comminutor as disclosed in Australian Patent Number 2002317626. The comminuted iron bearing material is approximately 20 to 50 microns in size.

[071] The term carbonaceous material refers to material or compound containing or composed of carbon including but not limited to coke, lignite, sub-bituminous coal, bituminous coal, anthracite, graphite, and mixtures thereof. It is readily appreciated that any appropriate carbonaceous material known within the art may be utilized. Additionally, the carbonaceous material may also include residual carbon by-product

from any coal process such as that disclosed in WO2011/047446. Similarly, the carbonaceous material may be comminuted using any means known within the art.

[072] Alternatively, the carbonaceous material may be coal with sufficient properties such as the appropriate type and quantity of ash content and low volatile material. Some carbon may originate from industrial by-products such as that from the processing of scrap car tyres or charcoal from wood or other charcoal products. Advantageously, the process can utilize low-grade carbonaceous material to still produce an improved and cost effective iron ore briquette thereby also improving the cost effectiveness of steel manufacturing thereafter.

[073] The fluxing material is selected from a group consisting of but not limited to cement, lime, silica, alumina and mixtures thereof. It is readily appreciated that any appropriate fluxing material known within the art may be utilized. The fluxing material needs to be high in calcium oxide. Portland cement or lime is the preferred fluxing material for the process of the present invention. Additionally, Portland cement also provides strength to the green briquette formed wherein the green briquette may be required to be aged for up to 7 days to reach sufficient green strength.

[074] The primary binder material is selected from a group consisting of borax, soda ash and mixtures thereof. However, it is readily appreciated that any appropriate binder material known within the art may be utilized. The binder material assists to produce a low temperature slag to maintain structure of the iron ore briquette when the iron ore briquette is subjected to heat. The binder material is well distributed throughout the iron ore briquette to keep the iron ore particles and the carbon particles in close contact until such time as the iron oxide is completely reduced.

[075] The iron bearing material and carbonaceous material must be very fine such that when the briquette mixture is combined and compacted into a briquette, there is intimate surface contact between the iron bearing material, the carbonaceous material and fluxing material.

[076] The increased reactivity and reduction of the iron ore briquette formed from the process of the present invention is attributed to the addition of a metallic particulate material to the briquette mixture. The metallic particulate material includes but is not limited to ferrous filings, particularly fine iron filings. Additionally, the fine iron filings can also be recycled material from the present briquette production process and would be up to 10% of the total output of reduced iron ore briquettes.

[077] The metallic particulate material is added and mixed to the briquette mixture prior to compaction of the briquette mixture. Accordingly, the metallic particulate material is dispersed throughout the compacted briquette. The metallic particulate material effectively provides numerous sites throughout the iron ore briquette whereby reduction can propagate.

[078] Figure 6A and 6B illustrates the increased reactivity and reduction of the iron ore briquette 23 formed according to the process of the present invention, when subjected to electromagnetic energy 25. The metallic particulate material 27 is dispersed throughout the iron ore briquette 23. When the iron ore briquette 23 is subjected to electromagnetic energy 25, the metallic particulate material 27 attracts the electromagnetic energy 25 creating numerous reaction sites 29 throughout the iron ore briquette 23. As reduction occurs at each of the sites 29 the overall reactivity and reduction of the iron ore briquette 23 is increased and enable a more complete reduction of the iron ore briquette 23 in the production of pig iron.

[079] Experimentation and research conducted by the applicant revealed an optimum frequency of electromagnetic energy of 100 to 500 kHz, for the reduction of the iron ore briquettes. Induction furnaces operating at such frequencies are available in commercial sizes.

[080] In addition to the primary binder, hot water and a further secondary binder is added to the briquette mixture. The secondary binder including a combination of sodium silicate solution. The hot water and sodium silicate solution assist to maintain the close contact between the iron bearing material and carbonaceous material within the

briquette mixture. Mixing of the briquette mixture may be achieved via a screw mixer or rotary tumbler or any appropriate means known within the art.

[081] The hot water enabling the briquette mixture to be mixed and kneaded into a dough. Additionally, the hot water also introduces moisture to the briquette mixture such that the compacted green briquettes formed thereafter will have sufficient moisture to assist in the reactivity and reduction of the iron ore briquette. Wherein the iron ore briquette is subjected to electromagnetic energy, the water is converted to hydrogen through a reaction with carbon or carbon monoxide as follows:

$$H_2O + C \rightarrow CO + H_2$$
$$Fe_2O_3 + CO \rightarrow 2FeO + CO_2$$
$$Fe_2O_3 + H_2 \rightarrow 2FeO + H_2O$$
$$CO + H_2O \rightarrow CO_2 + H_2$$
$$FeO + CO \rightarrow Fe + CO_2$$
$$FeO + CO \rightarrow Fe + CO_2$$
$$FeO + H_2 \rightarrow Fe + H_2O$$

[082] Hydrogen is an effective reducing agent due to its smaller size in comparison to carbon monoxide. Additionally, reduction of the iron ore within and around the iron ore briquette solves the problem faced by conventional iron ore briquettes where the reduction only occurs on the outer face of the briquette and forming a layer of reduced iron thereby preventing further and complete reduction of the whole briquette.

[083] The briquette mixture is fed into a suitable pre-compactor or a briquetting machine such as a rotary briquetting machine for compaction into green briquettes.

[084] The briquettes may be subjected to a primary curing comprising of drying and aging the green briquette at an ambient temperature for up to 7 days. Once aged, the briquettes may be subject to a pre-heating treatment in an induction furnace to strengthen the briquettes if being used as feedstock for a blast furnace. Alternatively,

the aged briquettes may be used as feedstock for melting and reduction in an induction furnace.

[085] As disclosed above, the iron ore briquettes formed from the process of the present invention are suitable for use as feedstock in either an induction furnace or blast furnace. If the iron ore briquettes are to be utilized as feedstock in a blast furnace, the iron ore briquettes must have sufficient strength to withstand the weight of the charge in the blast furnace. In this regard, the iron ore briquettes may be subjected to a pre-heating treatment in an induction furnace. The pre-heating treatment assists to strengthen the iron ore briquettes for use in the blast furnace thereafter.

[086] Alternatively, if the iron ore briquettes are to be used as feedstock for an induction furnace, the aged green briquettes or pre-heated briquettes may be subjected to curing in a rotary kiln. It would be readily appreciated that curing may be achieved using any appropriate means known within the art. Curing of the briquettes occurs between 600-700°C, and once cured the iron ore briquettes are feed into an induction furnace for reduction and melting to pig iron thereafter.

[087] Figure 7 illustrates an embodiment of a process of manufacturing pig iron utilizing iron ore briquettes formed according to the process of the present invention. The iron ore briquettes 31 are fed into a rotary kiln 33 at arrow A and subjected to a curing. The cured iron ore briquettes 31 are then fed into the smaller diameter induction furnace 35. The molten pig iron 37 and slag 39 go into the larger reservoir 41. The larger reservoir 41 is also induction heated via induction coils 43, where the slag 39 separates to the top of the reservoir 41 while the pig iron 37 separates to the lower part of the reservoir 41. The slag 39 and the pig iron 37 are tapped regularly, with the molten pig iron 37 delivered via arrow B to a converter 45 where oxygen 47 is blown into the converter 45 to produce steel thereafter, arrow C. The molten steel may then be molded into ingots or fed into a continuous casting machine.

CLAIMS

1. A process for producing and reducing an iron ore briquette, the process comprising the steps of:

    a. combining together a comminuted iron bearing material, a comminuted carbonaceous material, a fluxing material and a primary binder material to form a briquette mixture;

    b. adding a metallic particulate material to the briquette mixture;

    c. adding hot water and a secondary binder material to the briquette mixture;

    d. kneading the briquette mixture together;

    e. compacting the briquette mixture under pressure to form a green briquette,

    f. subjecting the green briquette to a primary curing to form a stable iron ore briquette or pre-heating the green briquette by conventional or induction heating means up to a temperature of 800°C; and

    g. feeding the green briquette or pre-heated green briquette to a furnace to produce pig iron,

    wherein when the iron ore briquette is subjected to electromagnetic radiation, the metallic particulate material dispersed within the iron ore briquette promotes formation of increased reactivity sites and thereby increase the reduction of the iron ore briquette to form pig iron.

2. The process according to claim 1 further characterized wherein, the metallic particulate material is 1 to 10% by weight of total weight of the comminuted iron oxide and the comminuted carbonaceous material of the briquette mixture.

3. The process according to claims 1 and 2 further characterized wherein, the metallic particulate material comprises of very fine ferrous filings.

4. The process according to claims 1 to 3 further characterized wherein, the comminuted iron bearing material is selected from a group consisting of hematite, magnetite, taconite, limonite, siderite, pyrites, chromite and mixtures thereof.

5. The process according to claims 1 to 4 further characterized wherein, the comminuted carbonaceous material is selected from a group consisting of coke, lignite, sub-bituminous coal, bituminous coal, anthracite, graphite, and mixtures thereof.

6. The process according to claims 1 to 5 further characterized wherein, the comminuted carbonaceous material in the briquette mixture being in excess of 20% of the stoichiometric ratio required for reduction the iron oxide material.

7. The process according to claims 1 to 6 further characterized wherein, the fluxing material is 2 to 8% by weight of total weight of the comminuted iron bearing material and the comminuted carbonaceous material of the briquette mixture.

8. The process according to claims 1 to 7 further characterized wherein, the fluxing material is selected from a group consisting of cement, lime and mixtures thereof.

9. The process according to claims 1 to 8 further characterized wherein, the primary binder material is selected from a group consisting of borax, soda ash and mixtures thereof.

10. The process according to claim 9 further characterized wherein, the borax is 2 to 8% by weight of total weight of the comminuted iron bearing material and the comminuted carbonaceous material of the briquette mixture.

11. The process according to claims 9 and 10 further characterized wherein, the soda ash is 1 to 5% by weight of total weight of the comminuted iron bearing material and the comminuted carbonaceous material of the briquette mixture.

12. The process according to claims 1 to 11 further characterized wherein, the secondary binder material comprises of an aqueous sodium silicate solution.

13. The process according to claims 1 to 12 further characterized wherein, the primary curing comprises of drying and aging the green briquette at an ambient temperature for up to 7 days.

14. The process according to claims 1 to 13 further characterized wherein, pre-heating of the green briquette occurs via heating in a conventional heating means or induction heating means.

15. The process according to claim 14 further characterized wherein, the conventional heating means comprises a rotary kiln.

16. The process according to claims 1 to 15 further characterized wherein, the electromagnetic radiation applied to the iron ore briquette is between 100 to 500 kHz.

17. The process according to claim 16 further characterized wherein, the electromagnetic radiation is applied via an induction furnace.

18. The process according to claims 1 to 18 further characterized wherein, the furnace comprises a blast furnace, an electric arc or induction furnace.



FIGURE 1



FIGURE 2

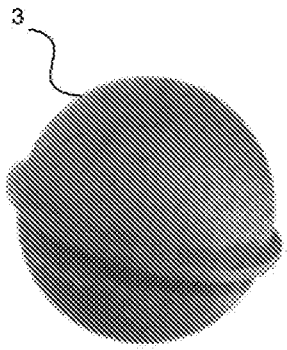


FIGURE 3A

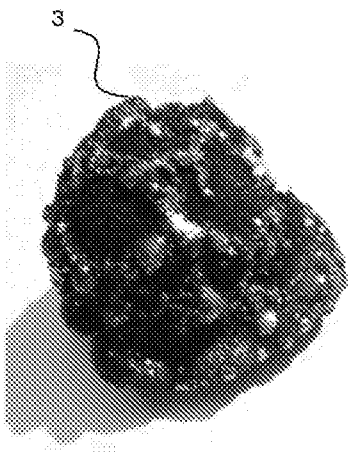


FIGURE 3B

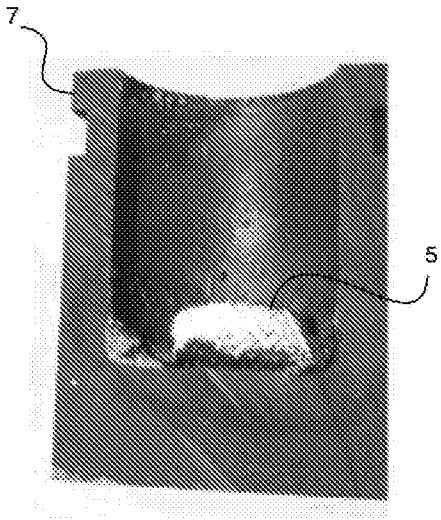


FIGURE 3C

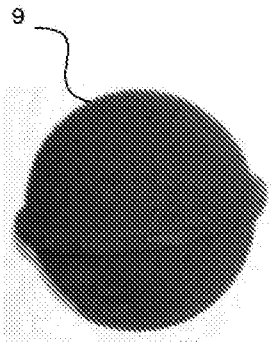


FIGURE 4A

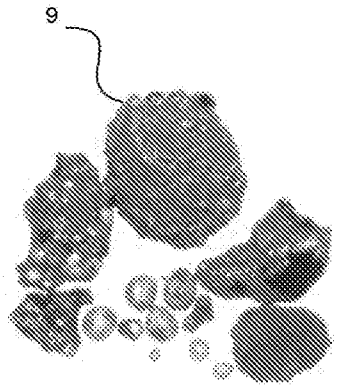


FIGURE 4B

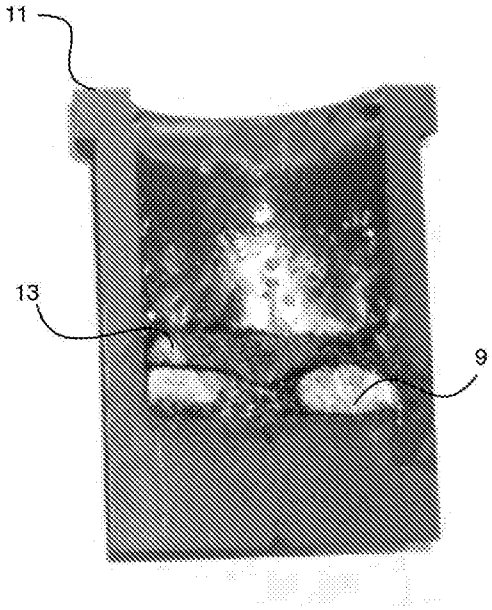


FIGURE 4C

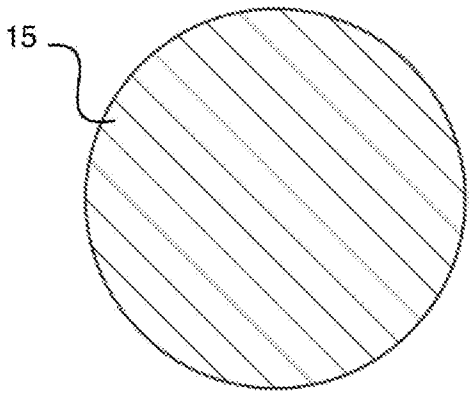


FIGURE 5A

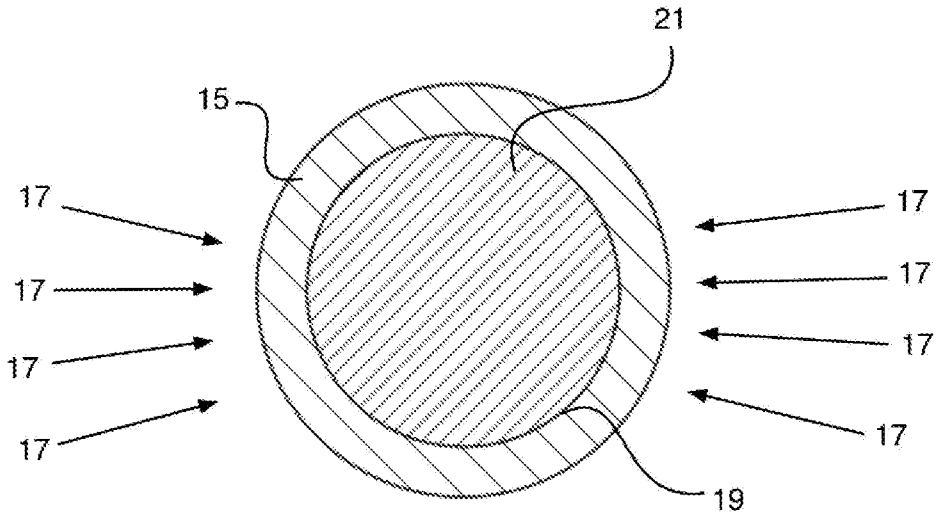


FIGURE 5B

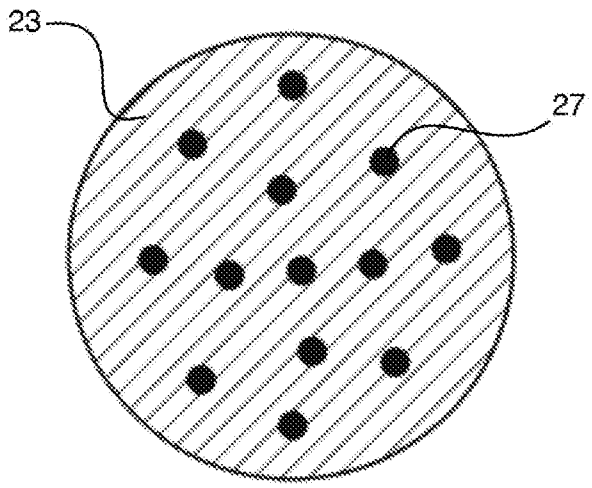


FIGURE 6A

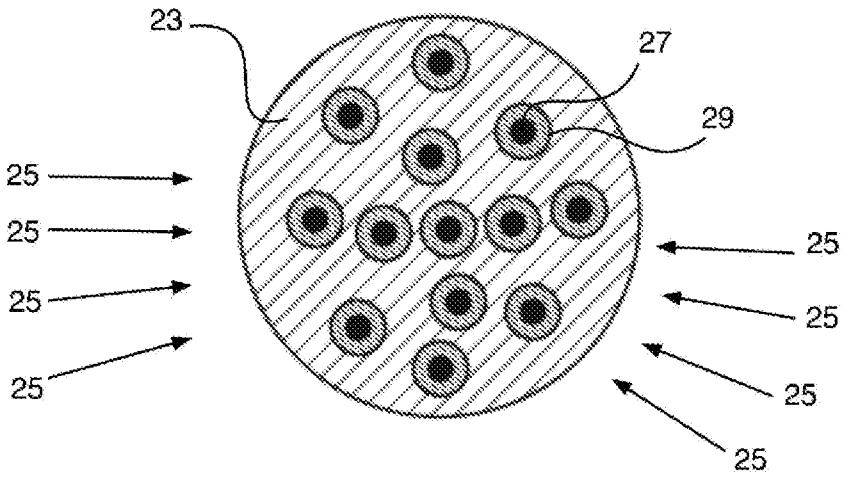


FIGURE 6B

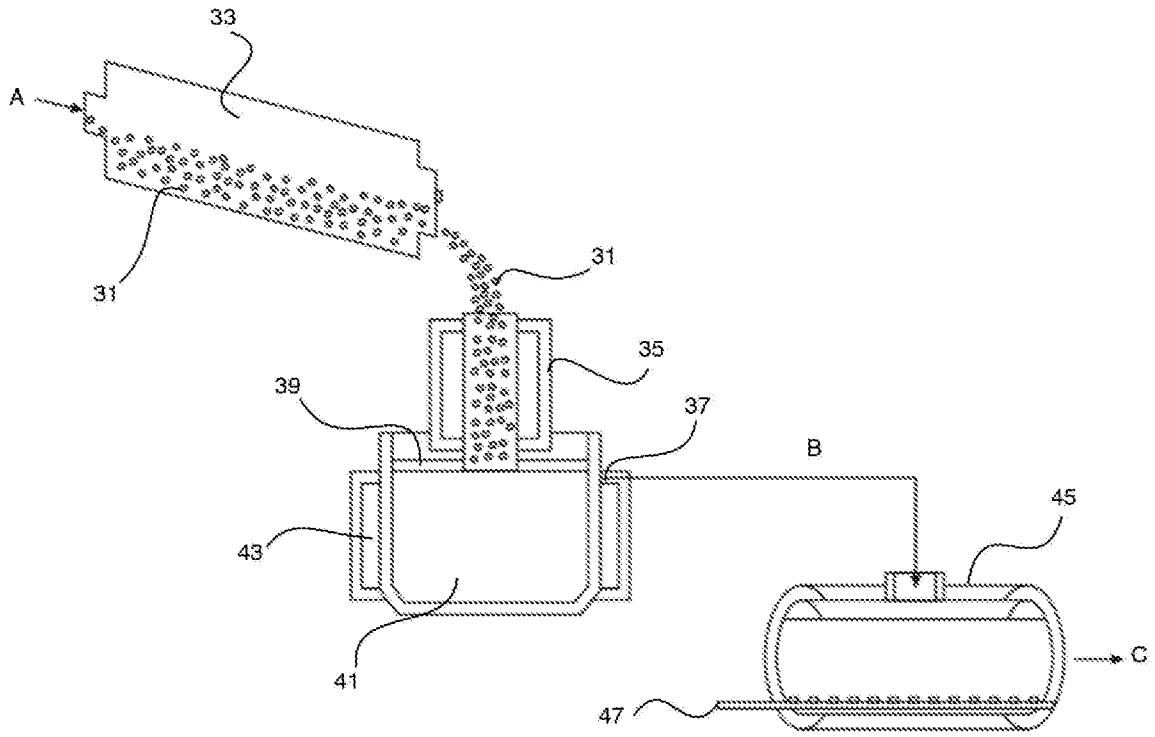


FIGURE 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2014/000806

A. CLASSIFICATION OF SUBJECT MATTER

C21B 11/10 (2006.01) C21B 13/14 (2006.01) C21B 13/12 (2006.01) C22B 1/245 (2006.01) C22B 5/10 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Derwent WPI & EPODOC & All English language full text patent databases: IPC/CPC C21B11/10/LOW, C21B13/14/LOW, C21B13/12/LOW, C21B11/00, C21B11/06, C22B1/245/LOW, C22B5/10/LOW and various combinations of keywords: briquette, pellet, tablet, iron, haematite, magnetite, carbon, coal, lignite, metal, scrap, ferrous, particle,grain, filing, powder, reactive, seed, nucleate, pig-iron, heat, em induction, melt, fuse, and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 November 2014	03 November 2014

Name and mailing address of the ISA/AU	**Authorised officer**
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INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2014/000806**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4129437 A (TAGUCHI et al) 12 December 1978 See column 3 lines 14-21, 40.	1-18
A	US 2005/0092130 A1 (GOLBERGER et al) 05 May 2005 See para [0017], claim 17.	1-18
A	EP 0960952 A1 (GLOSTER N.V.) 01 December 1999 See para [0044].	1-18
A	EP 2202324 A1 (NIPPON STEEL CORP. et al) 30 June 2010 See para [0056]	1-18
A	EP 0208032 A1 (NIPPON KOKAN KABUSHIKI KAISHA) 14 January 1987 See column 3, claims 1-4	1-18
A	AU 417146 B2 (McDOWELL-WELLMAN ENGINEERING CO.) 17 September 1971 See page 5 lines 5-18	1-18

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2014/000806**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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EP 0960952 A1	01 December 1999	IT GE980041 A1	29 Nov 1999
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EP 2202324 A1	30 June 2010	JP 2009079289 A	16 Apr 2009
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AU 417146 B2	17 September 1971	AU 1813167 A	29 Aug 1968

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.