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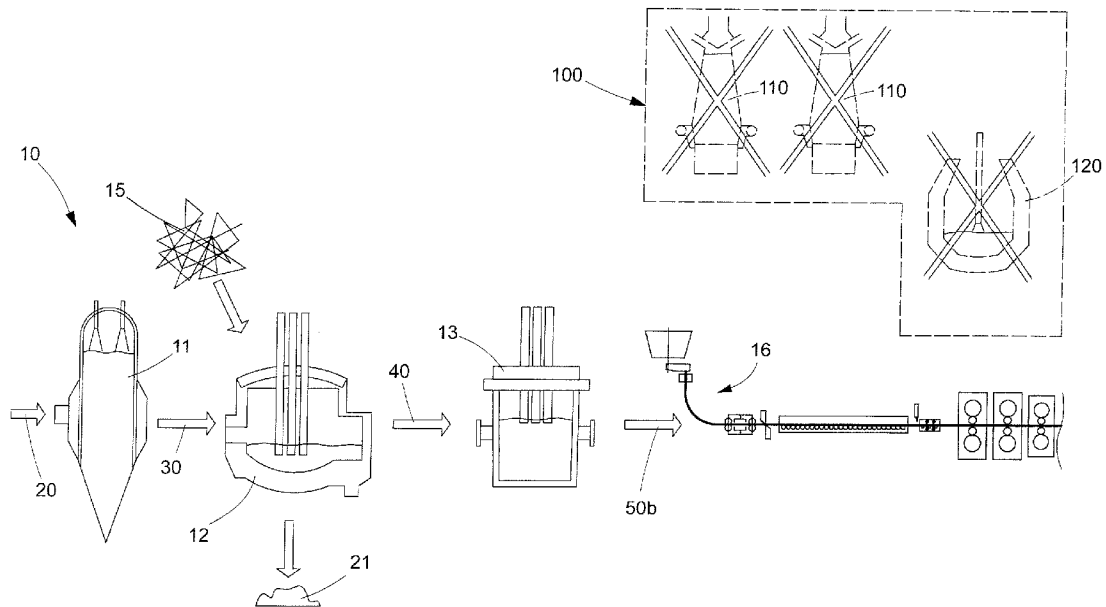


fig. 2

(57) Abstract: Method and plant (10) for producing steel comprising at least a first step of direct reduction in which, by means of a direct reduction plant (11), the reduction of an iron ore (20) is carried out, so as to obtain a ferrous material (30), and at least a second step of melting only in which, by means of an electric melting furnace (12), the ferrous material (30) is melted, generating a volume of slag (21) and a volume of liquid metal (40), the latter having a carbon percentage content of less than or equal to about 1%.



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“METHOD FOR PRODUCING STEEL AND CORRESPONDING PLANT”

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FIELD OF THE INVENTION

5 The present invention concerns a method and a corresponding plant for producing steel, preferably starting from iron ore, with lower direct CO₂ emissions compared to current integral cycle plants. The present invention is advantageously applied in the temporary and progressive replacement of known plants, that is, blast furnaces, in order to reduce environmental impact, particularly in terms of emissions, guaranteeing the same quality of liquid steel.

BACKGROUND OF THE INVENTION

10 It is known that, to produce steel starting from iron ore, the most commonly used methods and plants (with an estimate of around 70% of world production) currently pass through the so-called integral cycle, that is, the use of one or more blast furnaces (BF) that produce cast iron (with percentages of carbon C>2.6%, on average C: ~4.5%) starting mainly from iron ore and carbon coke. Oxygen converter furnaces (BOF) are normally provided downstream of the blast furnaces, used for the decarburization of the cast iron through the oxidation of the excess carbon, for the conversion into liquid steel and for the removal of slag impurities, in order to obtain a material suitable for casting, after appropriate secondary
20 metallurgy treatment.

Typically, each blast furnace is fed with iron ore in the form of Sinter and/or pellets and/or lump, with an iron concentration that can be defined as medium-low, typically comprised between 62% and 65%, or even higher. The residual oxides are acid-based (SiO₂%>CaO%) or neutral, and the concentration of mixed oxides
25 in the iron ore is typically 5% ÷ 10%.

This type of plant, while allowing a wide production flexibility, produces high direct emissions of CO₂ into the atmosphere, due to the use of fossil fuels and the chemical transformations that occur in the decarburization of the cast iron.

30 In the iron ore steel production sector, there is an ever increasing need to significantly reduce direct emissions of CO₂ from fossil fuels, a need which is set to grow in the future, with the aim of even substantially eliminating such emissions within a few decades, in light of the environmental objectives that international communities aim to set themselves.

For these reasons, there is a tendency to reduce setting up new plants with an integral blast furnace and BOF cycle or, at least, strategies are being planned for the progressive replacement of existing plants, in particular blast furnaces, with plants with a lower environmental impact.

5 However, the replacement of traditional plants is temporally limited by their economic and operational amortization, and by the need to dispose of the components of the blast furnace, in particular their refractories, which, on average and by way of example, have an expected end-of-life of about 30-50 years from their installation and require investments for renovation in the order of tens of
10 millions of euros. Because of this, once the blast furnace is restored, it is taken to its end-of-life. These timings, however, are not always consistent with international indications of ecological transition, for the purposes of achieving the common objectives of direct emission of CO₂.

Other known solutions for steel production starting from iron ore provide to use
15 direct reduction plants (DRPs) in which, by employing natural gas (NG) used as a precursor for the generation of the reducing gas mixture, the reduction of the iron ore into high metallization pellets (DRI) is performed, which are then melted in an electric arc furnace (EAF) and suitably treated with secondary metallurgy to be subsequently fed to the casting.

20 Direct reduction plants, which use natural gas for the generation of the reducing gas, are generally and preferably fed with iron ore in the form of pellets, sometimes with the addition of lump. These materials are characterized by an iron concentration that can be defined as medium-high, that is, comprised in a range between about 65% and about 68% and more. The residual oxides generally have
25 a basic or neutral gangue ($\text{CaO} \geq \text{SiO}_2$). In this case, the concentration of mixed oxides, or gangue, is typically comprised between about 4% and about 6%.

Considering that the market is moving more and more toward this type of solution, the ore with a medium-high concentration of iron oxides required by DRPs is subject to an increase in demand, with the progressive decrease in
30 availability, quality, and increase in prices.

Alternatively, it is known to enhance the step of concentrating the metal charge, through a so-called “beneficiation” treatment, of the iron ore with traditional concentration, via chemical attack. This additional step clearly leads to a further

increase in the cost of quality iron ore and the need to dispose of the resulting fluids. The subsequent melting of this DRI in an EAF allows to produce high-quality liquid metal (without impurities that are difficult to remove such as Cu and Sn) and a quantity of slag that depends on the characteristics of the gangue
5 contained in the DRI.

It is also known to produce steel directly by means of a scrap-fed EAF furnace.

This technology, although industrially better known and more advanced, especially for the direct production of steels, despite being considered to date the technology with the lowest environmental impact, presents problems related to the
10 supply of scrap, in particular due to the increase in demand.

Applying this technology to the complete replacement of the integrated blast furnace and BOF plants, it is reasonable to expect a production standstill, precisely because of the depletion of the available scrap. In fact, if the majority of the world's steel production were to be diverted to this technology, that is, produce most of the
15 steel starting from scrap, there would be a shortage of scrap and a rise in its price, which would put the cost of production out of the market and could lead to supply shortages.

In this situation, it is therefore appropriate to try to use, at least in part, iron ore to maintain production, with the consequent environmental impact issues
20 mentioned above.

Returning to the solutions that provide to use DRP technology, there are also known solutions in which the reduction is carried out with the use of hydrogen gas, used to partly or totally replace the natural gas used in the reduction process. In this way, it is possible to decrease the carbon content in the process gas and the
25 consequent formation of CO₂ during direct reduction, and consequently increase the hydrogen content.

Document US 2023/0160028 concerns a process for producing a carburized sponge iron, wherein iron ore is reduced in a direct reduction reactor, using a reducing gas, and then the reduced iron ore is sent into a carburizing unit where it
30 is carburized using a carburizing gas.

This solution allows to keep the reduction and carburization steps separate; however, the carburization is performed on solid material, for example in the form of pellets, which can still have a high carbon content.

There is therefore the need to perfect a method and to provide a plant that can overcome at least one of the disadvantages of the state of the art.

To do this it is necessary to solve the technical problem of producing steel from iron ore, or scrap, reducing direct CO₂ emissions.

5 In particular, one purpose of the present invention is to perfect a method and provide a plant for producing steel with lower direct CO₂ emissions, and without impacting the quantity and quality of the steel produced.

Another purpose of the present invention is to perfect a method and provide a plant for producing steel that can progressively replace current integrated cycle
10 plants, substantially respecting the economic and operational amortization plans of the refractory components of existing blast furnaces, and guaranteeing quality and annual production at least at current values.

The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other
15 purposes and advantages.

SUMMARY OF THE INVENTION

The present invention is set forth and characterized in the independent claims. The dependent claims describe other characteristics of the present invention or variants to the main inventive idea.

20 In accordance with the above purposes and to resolve the technical problem disclosed above in a new and original way, also achieving considerable advantages compared to the state of the prior art, a method according to the present invention for producing steel comprises at least a first step of direct reduction in which, by means of a direct reduction plant, a reduction of an iron ore is carried out, by means
25 of direct reduction reactions with the use of a reducing gas of any origin, so as to obtain a ferrous material, preferably with a high metallization.

According to the invention, the iron ore can be provided in the form of Sinter and/or pellets and/or lump, with a medium-low iron concentration, typically comprised between 62% and 65%, or higher, in a range comprised between
30 approximately 65% and approximately 68%, while the natural gas used can be a mixture of gases consisting of carbon monoxide, methane, light hydrocarbons, small percentages of other gases, and possibly some contaminants.

In particular, it is provided that the gas used comprises a percentage of

hydrogen, possibly increasing over time, assuming an increase compared to the state of the art, going from a ratio of 60-40%, reaching a ratio of 80% of H₂ and 20% CH₄ with other residual gases, or even substantially 100% of H₂ content.

5 The method subsequently comprises at least a second step of melting only in which, by means of an electric melting furnace, preferably an electrode or induction furnace, the ferrous material is melted, generating a volume of slag and a volume of liquid metal, the latter having a carbon percentage content of less than or equal to about 1%.

10 Advantageously, during the second step of melting only, oxygen can be injected, with a content for example of between about 5 Nm³/t liquid metal and about 15 Nm³/t liquid metal, in order to reduce the final carbon content in the tapped liquid metal to below 1% and in order to begin the dephosphorization of the liquid metal. In the same way, the Applicant has experimented that the slag thus separated has a low concentration of iron oxide FeO, comprised between about 10% and about 15%.

15 The production of liquid metal with carbon less than or equal to approximately 1% allows to improve production efficiency and the performance of the electric melting furnace. This is combined with advantages linked to the reduction of operating times which lead to a greater balance in energy and overall production costs. Ultimately, the aim of the melting process described here is to separate the
20 slag from the liquid metal, minimizing the addition of additives and producing a liquid metal to be used in the subsequent treatment stages.

Consequently, with the solution according to the present invention, direct CO₂ emissions from direct reduction can be progressively reduced, potentially eliminating them, with an exclusive use of hydrogen gas in this step of the method.

25 In accordance with one aspect of the present invention, in the presence of at least one blast furnace supplying a portion of material for the production of the steel, the method subsequently comprises at least a third step of recarburization in which, in a recarburization station, a desired quantity of carbon is added to the liquid metal at exit from the electric melting furnace, so as to produce a carburized
30 liquid metal with a desired percentage of carbon, whether this can be classified as a cast iron, or as a steel, depending on requirements. The carbon percentage can be comprised between 1% and 3%.

In an advantageous preferential embodiment of the present invention, in the

third step of recarburization graphite can be used in lumps or flux cored wire, containing graphite or CaC_2 , which is gradually added to the metal bath.

By doing so, according to the present invention, the ferrous metal alloy is produced starting from a direct reduction of ore to obtain a ferrous material, preferably without using fossil fuels and, substantially, with reduced CO_2 emissions compared to the blast furnace. Furthermore, by providing to use the electric furnace for melting and slag separation only, it is possible to start from an ore with a medium-low iron concentration, to the advantage of supply and reduced starting costs.

In fact, with the present invention it is also possible to use iron ore with these medium-low concentrations, since the aim is to produce, in the second step of melting only, a liquid metal with a carbon percentage lower than or equal to 1%, so as to optimize the production efficiency of the electric furnace, reducing the time and energy required for melting, as well as obtaining an effective separation of slag which allows to eliminate the unwanted gangue linked to the concentration of iron oxide in the starting mineral.

This combination of advantages allows to significantly reduce the environmental impact that normally occurs when producing cast iron or steel with traditional methods.

Therefore, by actuating a targeted recarburization in the third step of the method according to the present invention, starting from a liquid metal with a carbon percentage lower than or equal to approximately 1%, a liquid metal can be produced which finds advantageous application in the possible progressive integration of traditional productions with integral cycle, until the latter is decommissioned completely.

In accordance with one aspect of the present invention, the method comprises a fourth step of oxidation, in which by means of at least one oxygen converter furnace (BOF) the previously carburized liquid metal is mixed with a determinate quantity of cast iron produced in the at least one blast furnace, and together they are subjected to at least one desired oxygenation for the oxidation of the excess carbon in order to produce steel, which is subsequently sent to a step of continuous casting. Scrap can possibly be added in this step.

In other words, as blast furnaces are progressively decommissioned in a

traditional plant, it is possible to replace the production of cast iron with the method and plant according to the present invention, initially reducing CO₂ emissions, at least as regards the part linked to the production of ferrous material by direct reduction carried out with percentages of hydrogen gas which are progressively prevalent with respect to traditional hydrocarbons, and in the production of a liquid metal with the minimum concentration of carbon required for the subsequent treatments.

In these solutions of progressive replacement of known plants with the solution according to the present invention, a recarburization can be carried out in the third step up to carbon percentages ranging from about 1.0 to about 3%, to then make the ferrous metal alloy thus obtained flow toward oxygen converter furnaces (BOF), into which the productions of the remaining blast furnaces also flow, so as to keep productivity unchanged. The mixture between the two contributions will have a C concentration in the 2.5% - 4.5% range, with an optimal value in the 3% - 3.5% range.

A step of mixing between the two contributions of liquid metal, that is, carburized metal and cast iron, can also optionally take place in a reactor provided in a mixing station that precedes the BOF, so as to promote mixing before the decarburization treatment and/or to optimize the logistics of the plant. Scrap can possibly be added in this step.

The concentration of carbon that has to be present in the carburized liquid metal is calculated using the following formula:

$$\%C = [3.2 * (x + y) - x * 4.5]/y$$

where:

x: fraction of liquid metal coming from the blast furnace, with carbon concentration equal to 4.5%;

y: fraction of liquid metal coming from the recarburization process, with carbon concentration to be determined.

In this way, when a second blast furnace of the same plant is decommissioned, a second production line according to the present invention can advantageously be provided, and so on until all the blast furnaces have been replaced.

In accordance with another aspect of the present invention, following the dismantling of all the blast furnaces present in the metal production plant, the third

step of recarburization is eliminated together with the one or more oxygen converter furnaces, and secondary metallurgy processes occur in the recarburization station in order to produce the steel which is subsequently sent to the continuous casting step.

5 In accordance with another aspect of the present invention, in the second step of melting only, the electric melting furnace can also be fed, as well as with the ferrous material from direct reduction, with scrap, the latter in a substantially traditional manner, in baskets or in continuous, hot charging.

10 In fact, with the solution according to the present invention the use of scrap can be substantially maintained in the traditional values, depending on the supply capacity and/or cost thereof, since the steel is produced starting from direct reduction, with reduced CO₂ emissions, and the scrap is used only as a selective addition to the electric melting furnace.

15 The present invention also concerns a plant for producing steel comprising at least one direct reduction plant configured to carry out a reduction of an iron ore, by means of natural gas, so as to obtain a ferrous material.

20 The plant for producing steel comprises at least one electric melting furnace, disposed downstream of the at least one direct reduction plant and suitable to subject the ferrous material to melting, so as to generate a volume of slag and a volume of liquid metal, the latter having a carbon percentage content of less than or equal to about 1%.

25 According to one aspect of the present invention, in a first configuration, the plant for producing steel comprises at least one recarburization station disposed downstream of the at least one electric melting furnace and suitable to add a desired percentage of carbon to the liquid metal, so as to produce a carburized metal with a desired percentage of carbon, at least one blast furnace suitable to supply a determinate quantity of cast iron for the production of the steel, and at least one oxygen converter furnace suitable to receive, and at least to oxidize the excess carbon contained in, the carburized metal and the cast iron.

30 In a second configuration, converted with respect to the first configuration, the at least one electric furnace is also suitable to carry out refining processes on the liquid metal, and the recarburization station is suitable to carry out secondary metallurgy processes on the refined liquid metal in order to produce the steel to be

sent to continuous casting. In the second configuration, the plant for producing steel has no blast furnaces and oxygen converter furnaces.

DESCRIPTION OF THE DRAWINGS

These and other aspects, characteristics and advantages of the present invention will become apparent from the following description of an embodiment, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 schematically shows a layout of a plant for producing steel according to the present invention, applied to the progressive replacement of a known plant;
- fig. 2 schematically shows a layout of the plant of fig.1 once the replacement of the known plant has been completed.

We must clarify that the phraseology and terminology used in the present description, as well as the figures in the attached drawings also in relation as to how described, have the sole function of better illustrating and explaining the present invention, their purpose being to provide a non-limiting example of the invention itself, since the scope of protection is defined by the claims.

To facilitate comprehension, the same reference numbers have been used, where possible, to identify identical common elements in the drawings. It is understood that elements and characteristics of one embodiment can be conveniently combined or incorporated into other embodiments without further clarifications.

DESCRIPTION OF AN EMBODIMENT OF THE PRESENT INVENTION

With reference to fig. 1, a plant 10 according to the present invention is shown, applied as a progressive replacement of a traditional type plant 100.

According to the purposes of the present invention, the plant 10 is of the type suitable for the production of a metal alloy, whether this is a cast iron 50a or a steel 50b, starting from iron ore 20. According to some variants that refer to the solution according to the present invention, the concentration of iron can be either medium-low or medium-high, depending on the availability of purchase.

The traditional type plant 100 is of the integral cycle type, that is, provided with a plurality of blast furnaces 110, for example at least two, which produce cast iron 50a through reduction of the iron ore 20 with carbon-coke, and feed the cast iron 50a to an oxygen converter furnace, or BOF 120, in which it is oxidized for the conversion into molten steel 50b, and for the removal of the slag impurities 121 and the development of CO subsequently oxidized to CO₂. Scrap can possibly be

added in this step.

As shown in fig. 1, as part of a strategy of progressive removal and replacement of traditional plants 100 with a plant 10 according to the present invention, when the shutdown of a blast furnace 110 is justified, for example when the refractories
5 are exhausted operationally, a production line of the plant 10 according to the present invention is installed in parallel and as partial replacement, but initially keeping the BOF.

The plant 10 according to the present invention essentially comprises a direct
10 reduction plant, or DRP 11, an electric furnace 12 for slag melting and separation only (therefore no possible refining steps are provided in this part of the process, which are delegated to the following steps) and a recarburization station 13, which are disposed in substantial operational sequence to each other.

Although not specifically shown in the attached drawings, it is not excluded that the plant 10 according to the present invention can have a different layout from the
15 one schematically represented. For example, two or more DRPs 11 can be provided operatively in parallel and suitable to feed one or more electric furnaces 12 for melting only; in the same way, it is not excluded that two or more recarburization stations 13 can be provided, also in order to produce different types of cast irons 50a, or steels 50b, in parallel.

20 In the same way, different layouts can be studied and prepared in advance in order to guarantee the same, if not superior, production conditions as the traditional plant 100 that is being progressively replaced.

In the operational detail of fig. 1, one of the two blast furnaces 110 is decommissioned, while the other continues to traditionally produce cast iron 50a
25 to be fed to the BOF 120, for the removal of slag impurities 121 and the conversion into steel 50b.

In parallel, in place of the decommissioned blast furnace 110, the DRP 11 of the plant 10 according to the present invention is installed, which performs a reduction
30 of the iron ore 20 by means of natural gas preferably combined with hydrogen, so as to obtain a ferrous material by direct reduction, or DRI 30, with low, medium or high concentration of iron.

Again in order to reduce the environmental impact of the plant 10 according to the present invention, and in a manner coordinated with the technologies that allow

its effective production, the natural gas used for the direct reduction of the iron ore
20 can be progressively combined with hydrogen, until it is completely replaced
by it. In particular, it is provided that the gas used comprises a percentage of
hydrogen, possibly increasing over time, from at least 50%, assuming to reach a
5 preferential ratio of about 80% of H₂ and 20% of CH₄ with other residual gases,
although without excluding about 100% (99% plus any residuals).

The use of H₂ at 100% as a reducing gas, already provided for that matter in the
operational design of the DRP 11, allows for a complete extinction of CO₂
emissions connected to the reduction stage, producing a gaseous waste composed
10 essentially of water (FeO+H₂=Fe+H₂O).

The DRI 30 thus produced is, however, low in carbon, especially if processed
by means of hydrogen, and is subsequently fed to the electric furnace 12, which
essentially carries out the rapid melting of the DRI 30, preferably by means of
prevailing electrical energy, by means of electrodes and/or induction, with the
15 optimized addition of additives (for example CaO-MgO) for slag formation and
the safeguarding of the refractory, and with a possible minimum flow of O₂ (5-15
Nm³/t liquid metal) and addition of coal for the production of liquid metal with C
concentration <1%.

The liquid metal 40 thus obtained is then sent to a subsequent recarburization
20 station 13, where the subsequent recarburization takes place at a desired
concentration of carbon, by means of, for example, feeding of graphite in lumps or
flux cored wire containing graphite or CaC₂ into the bath, while not however
excluding alternative (although often less efficient) injections of coal in
powder/granules into the bath. This recarburization station 13 can, according to a
25 preferred but not limiting embodiment, be a ladle furnace LF equipped with
electrodes for the further heating of the metal and its carbon enrichment up to a
preferred, but not exclusive, maximum of 1.0 - 3%. Therefore, the output of this
recarburization station 13 is chosen according to the percentage of carbon to be
added to the liquid metal 40 so that the liquid metal to be sent to the BOF has at
30 least 3% - 3.5% C. In the case shown in fig. 1, the output of the recarburization
station 13 is a carburized metal 50c which is then fed to the BOF 120, in
conjunction with the cast iron 50a produced by the blast furnace 110 still in
operation and possibly with some scrap 15, if available at reasonable prices and

quantities for the manufacturer.

According to possible embodiments, a mixing station 14 can be provided in which the mixing between the carburized metal 50c and the cast iron 50a can take place, if necessary, in a dedicated vessel or reactor disposed upstream of the BOF 120, in order to optimize the mixing of the two metal contributions/or to optimize the logistics of the plant by acting, for example, as a buffer.

In fact, in this step of progressive replacement of the plant 100 with the plant 10 according to the present invention, the BOF 120 receives both the carburized metal 50c from the recarburization station 13, and also the cast iron 50a from the blast furnace 110 still in operation. This metal assembly is then decarburized, similarly to what happens with an integral type process, by the desired percentage in order to obtain a steel 50b with the desired carbon content.

The carbon percentage of the carburized metal 50c to be sent to the BOF 120 can be calculated using the following formula:

$$\%C = [3.2 * (x + y) - x * 4.5]/y$$

where:

x: fraction of liquid metal coming from the blast furnace, with carbon concentration equal to 4.5%;

y: fraction of liquid metal coming from the recarburization process, with carbon concentration to be determined.

By way of example, if the quantity of carburized metal 50c and cast iron 50a is in a quantity 40-60, the percentage of carbon present in the carburized metal 50b should be 1.25.

With the solution according to the present invention, the DRP 11 and the electric furnace 12 compensate for the replacement of a blast furnace 110, supplying a liquid metal 40 with a carbon percentage equal to or less than 1%, for the reasons and advantages described above, therefore this metal must then be recarburized, in the recarburization station 13, in order to obtain a carburized metal 50c suitable for treatment in the BOF 120, which was previously fed only by blast furnaces 110.

Secondary metallurgy processes will take place in the BOF 120, such as dephosphorization, decarburization, removal of gaseous nitrogen (N gas) by means of the CO bubbles generated by the decarburization process. Scrap can possibly be added in this step.

In order for these processes to take place efficiently, the percentage of carbon of the carburized metal 50c at exit from the recarburization station 13 will have to be within the range 1.0% ÷ 3.0%, if mixing the cast iron 50a coming from the blast furnace 110 and that coming from the recarburization station 13, a preferential ratio
5 >1 is maintained.

In the step of progressive replacement shown in fig. 2, the remaining example blast furnace 110 is also dismantled (in the initial case where there were two) and, consequently, the corresponding BOF 120, effectively eliminating all the equipment of the traditional plant 100.

10 It is clear that, depending on the specific operating conditions, volumes of steel to be produced, quality of the steel itself and other specific factors, the layouts shown can be modified in the design phase, for example by providing that secondary metallurgy processes take place in the recarburization station 13, or providing a single electric furnace 12, or other solutions that go beyond the
15 inventive idea.

In this final operating condition, that is, complete replacement of the traditional plant 110, the electric furnace 12 can be adapted by means of operational modifications, thus being able, in addition to melting, to also proceed with the subsequent refining of the liquid metal 40, operating appropriately in a known
20 manner in terms of injection of coal, O₂ (Nm³/t liquid metal), power kWh/t liquid metal, slagging agents CaO + MgO (kg/t liquid metal). In this step of complete replacement of the traditional plant 100, it is also possible to provide to feed the electric furnace 12 with metal scrap 15, both in baskets and continuously.

The liquid steel thus produced will be subjected to the secondary metallurgy
25 path (possibly with further passage in VD/VOD) in order to bring the steel 50b thus produced to the desired chemistry. In the example of fig. 2, the secondary metallurgy path is executed in the station 13 which, as mentioned above, no longer has any recarburization functionality.

The steel 50b produced is subsequently sent to the continuous casting 16.

30 It is clear that modifications and/or additions of parts may be made to the method and plant 10 as described heretofore, without departing from the field and scope of the present invention, as defined by the claims.

It is also clear that, although the present invention has been described with

reference to some specific examples, a person of skill in the art will be able to achieve other equivalent forms of method for producing steel and corresponding plant, having the characteristics as set forth in the claims and hence all coming within the field of protection defined thereby.

- 5 In the following claims, the sole purpose of the references in brackets is to facilitate their reading and they must not be considered as restrictive factors with regard to the field of protection defined by the claims.

CLAIMS

1. Method for producing steel (50b), comprising at least a first step of direct reduction in which, by means of a direct reduction plant (11), the reduction of an iron ore (20) is carried out with the use of gas, so as to obtain a ferrous material (30), **characterized in that** it subsequently comprises at least a second step of melting only in which, by means of an electric melting furnace (12), said ferrous material (30) is melted, generating a volume of slag (21) and a volume of liquid metal (40), the latter having a carbon percentage content of less than or equal to about 1%.
2. Method as in claim 1, **characterized in that** in the presence of at least one blast furnace (110) which supplies a portion of material for the production of said steel (50b), it subsequently comprises at least a third step of recarburization in which in a recarburization station (13) a desired quantity of carbon is added to said liquid metal (40), so as to produce a carburized metal (50c) with a desired percentage of carbon comprised between 1% and 3%.
3. Method as in claim 2, **characterized in that** it comprises a fourth step of oxidation, in which by means of at least one oxygen converter furnace (120) said carburized metal (50c) is mixed with a determinate quantity of cast iron (50a) produced in said at least one blast furnace (110), and together they are subjected to at least one desired oxygenation for the oxidation of the excess carbon in order to produce said steel (50b), which is subsequently sent to a step of continuous casting.
4. Method as in claim 3, **characterized in that** it comprises a step of mixing in which in a mixing station (14) said carburized metal (50c) is mixed with a determinate quantity of cast iron (50a) produced in said at least one blast furnace (110) before being introduced into said oxygen converter furnace (120).
5. Method as in claim 3 or 4, **characterized in that** after the dismantling of said at least one blast furnace (110), the third step of recarburization is eliminated together with said oxygen converter furnace (120), and in said recarburization station (13) secondary metallurgy processes occur in order to produce said steel (50b) which is cast in said step of continuous casting.
6. Method as in claim 5, **characterized in that** in said second step of melting only, processes of refining the liquid metal (40) also occur in said electric furnace (12).

7. Method as in any claim hereinbefore, **characterized in that** said iron ore (20) used in said first step of direct reduction comprises an iron concentration comprised between 62% and 68%.
8. Method as in any claim hereinbefore, **characterized in that** said reducing gas comprises hydrogen gas in combination with, or prevalent with respect to, a gas mixture substantially consisting of carbon monoxide, methane, light hydrocarbons, and small percentages of other gases.
9. Method as in any claim hereinbefore, **characterized in that** the oxidation to which the DRI produced by the direct reduction (30) is subjected, in said second step of melting only, uses about 5 Nm³/t and about 15 Nm³/t of O₂, **and in that** said slag (21) has an iron oxide concentration comprised between about 10% and about 15%.
10. Method as in any previous claim from 2 to 9, **characterized in that** in said third step of recarburization graphite is used in lumps or flux cored wire, containing graphite or CaC₂.
11. Method as in any claim hereinbefore, **characterized in that** in said second step of melting only said electric furnace (12) is also fed with scrap metal (15).
12. Plant (10, 110) for producing steel (50b) comprising at least one direct reduction plant (11) configured to carry out a reduction of an iron ore (20), by means of natural gas, so as to obtain a ferrous material (30), **characterized in that** it comprises at least one electric melting furnace (12), disposed downstream of said direct reduction plant (11) and suitable to subject said ferrous material (30) to melting, so as to generate a volume of slag (21) and a volume of liquid metal (40), the latter having a carbon percentage content of less than or equal to about 1%.
13. Plant (10, 110) as in claim 12, **characterized in that** in a first configuration, said plant (10, 110) comprises at least one recarburization station (13) disposed downstream of said at least one electric melting furnace (12) and suitable to add a desired percentage of carbon to said liquid metal (40), so as to produce a carburized metal (50c) with a desired percentage of carbon, at least one blast furnace (110) suitable to supply a determinate quantity of cast iron (50a) for the production of said steel (50b), and at least one oxygen converter furnace (120) suitable to receive, and at least to oxidize the excess carbon contained in, said carburized metal (50c), said cast iron (50a) and possibly scrap, **and in that** in a second configuration,

converted with respect to said first configuration, said at least one electric furnace (12) is also suitable to carry out refining processes on said liquid metal (40) and said recarburization station (13) is suitable to carry out secondary metallurgy processes on said refined liquid metal (40) in order to produce said steel (50b).

- 5 14. Plant (10) as in claim 13, **characterized in that** in said second configuration said plant (10) has no blast furnaces (110) and oxygen converter furnaces (120).

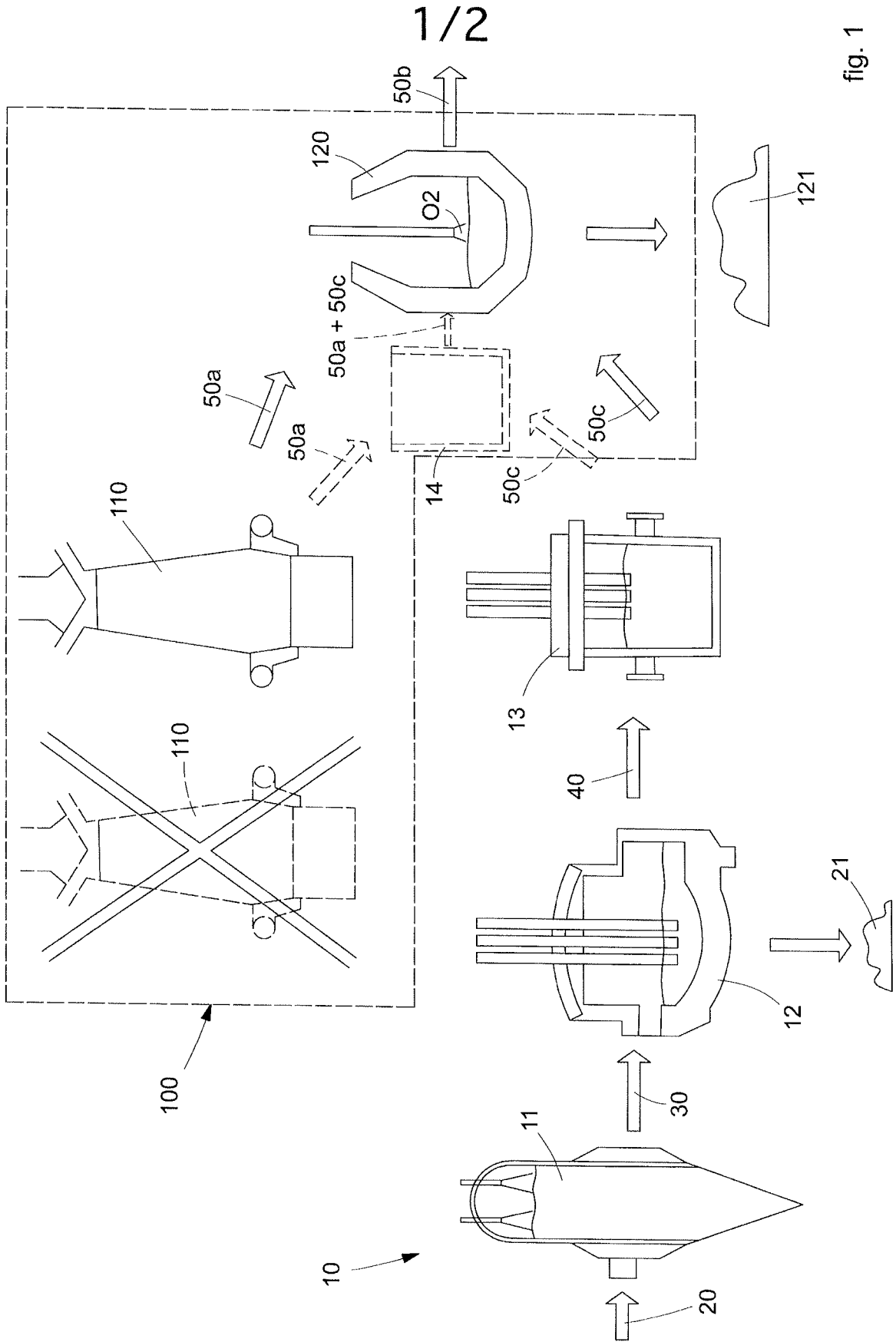


fig. 1

INTERNATIONAL SEARCH REPORT

International application No PCT/IT2024/050104

A. CLASSIFICATION OF SUBJECT MATTER
 INV. C21B13/00 C21B13/02 C21B13/14 C21C1/02 C21C1/04
 C21C7/00 C21C5/28

ADD.
 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)
 C21B C21C

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)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023/160028 A1 (HYLLANDER JENNY ANNA GUNILLA [SE] ET AL) 25 May 2023 (2023-05-25) figure 1 paragraphs [0066], [0079], [0083] -----	1 - 14
X	CA 2 302 244 C (KOBE STEEL LTD [JP]) 17 August 2004 (2004-08-17) figure 1 -----	12 - 14
A	US 4 889 323 A (PUSCH HERMANN [AT] ET AL) 26 December 1989 (1989-12-26) figure 1 claim 1 -----	3, 8

Further documents are listed in the continuation of Box C. 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 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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
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Date of the actual completion of the international search 19 August 2024	Date of mailing of the international search report 03/09/2024
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Porté, Olivier
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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