UNITED STATES PATENT OFFICE.

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PROCESS OF IMPROVING THE QUALITY OF MALLEABLE IRON AND STEEL.

1,053,454. Specification of Letters Patent. Patented Feb. 18, 1913.

No Drawing. Application filed December 21, 1910. Serial No. 598,625.

To all whom it may concern:

Be it known that I, OTTO THALLNER, a subject of the German Emperor, residing at Remscheid, in Germany, have invented a new and useful Process of Improving the Quality of Malleable Iron and Steel, of which the following is a specification.

My invention relates to a process for treating liquid malleable iron or steel to obtain an improved product having a peculiar crystalline grain very similar to, or substantially identical with, the grain which has always been observed in crucible steel and which apparently gives to such steel its great tenacity.

My process consists substantially in the treatment of liquid malleable iron or steel in the manner hereinbelow stated and more particularly claimed in the appended claims.

My process may be operated in a hearth-furnace (using this term to distinguish from the crucible or pot) and more particularly in an electric arc furnace, also on either an acid hearth or a basic hearth, whether the heat be furnished by gas, by electricity, or in any other suitable manner.

The characteristic steps of my process, as operated in practice, consist in adding to the slag, or providing therein for the presence of, a metallic oxid capable, under the conditions of melting practice, of giving oxygen to the bath of liquid malleable iron or steel which is covered by the slag; and also to add carbon to such bath. For instance, when working on an acid hearth with acid slag, I add to the slag a quantity of iron ore, and simultaneously provide for the presence of carbon in the bath by inserting carbon therein. This carbon is preferably in the form of the solid cooked mixture of iron, carbon, and tar, known as "carburite," which is particularly described in German Letters Patent No. 161,610, dated April 25, 1902. By using this carburite no difficulty is experienced in providing carbon both in and below the slag in an exactly calculated and desired manner during the process. I may, however, provide oxygen in any other manner than that above described which may be suitable for the purposes of the process, and I may also provide for the presence of the carbon in any other suitable manner, although I find that by far the best results are obtained by adding the carbon during the process substantially in the manner above described. While I prefer to commence with a liquid bath of metal which has been carburized to that content of carbon which is required for the finished metal, it is not essential that this be done, as I may, during the operation of my process and parallel thereto, carburize the metal to a higher degree of carbon.

It is not possible to state any definite proportion of iron ore to the amount of metal in the liquid bath as this amount will have to be determined in each case by the particular circumstances thereof. However, the amount of iron ore should not be so great as to provide an excess of oxygen which will thereafter remain in the bath and cause the resulting metal to be "red-short" or to contain "blow holes." The iron ore should, of course, be sufficient in quantity to insure the satisfactory performance of the process. Generally, it will be found that the iron ore should be somewhere between one and two and a half per cent. of the weight of the liquid metal. It will also not be possible to state exactly what proportion of carbon is to be added to the bath as this proportion depends upon the many circumstances of the case, for instance upon the amount of carbon already in the metal and the amount of carbon desired in the finished product.

I may, for instance when working with a bath of five thousand (5000) kilograms of liquid metal carburized to the content of carbon desired in the finished metal, for example to one per cent. of carbon, place therein from nine (9) to fifteen (15) kilograms of carbon in the form of carburite, but I may also add a larger quantity of carbon and withdraw the excess when samples taken from the bath show the required carbon content and the desired grain. I do not limit myself to the exact proportions or specific ingredients of the slag used in this specific process, but it may be stated that I may use 30–35% sand, 30–35% of lime and, to increase fusibility, 5–10% manganese ore, and add to this mixture 25–30% of iron ore. I may treat a bath of refined iron or steel in a basic furnace with a basic slag in a similar manner. The slag which I may use, without, however, limiting myself to any particular materials or proportions, may be composed of from about 40–50% lime and 20–25% fluorspar which may be par-

tially displaced by sand, and to which is added 30–35% of iron ore.

I may precede each of my operations by a preliminary treatment of the metal, in a basic furnace, with a non-oxygenous slag, that is to say, a slag free from oxid of iron, for the purpose of eliminating sulfur. The purified metal may be transferred to an acid hearth and therein subjected to the acid treatment above described; or it may be left in the basic furnace and therein subjected to the basic treatment as described above.

As the exact course of the reactions in a process of this kind, particularly at the high temperatures involved, is most difficult, if not impossible, to determine, I am not able to state positively what chemical changes take place in the metal bath when treated as above described. In submitting the following theory as to the reactions I desire to be understood as putting forward no more than a hypothesis, by which I desire in no way to be bound. The amounts of the various ingredients actually employed by me in working this process apparently justify the above hypothesis, and I have received much aid therefrom in determining what amounts to employ under various conditions and circumstances.

In the iron bath there are present, during the process, iron, carbid of iron and oxygen at a high temperature without acting upon one another. The reason for this inaction will be hereinafter explained. If the process is worked on a basic hearth, the slag will contain calcium oxid as well as iron ore (Fe_3O_4 or Fe_2O_3); and carbon, which is preferably added in the form of carburite, will be present both in the slag and in the bath. The calcium oxid reacts with the carbon, or with the carbid of iron of the bath, to form calcium carbid.

$$(A)\ CaO+3C=CaC_2+CO$$

or

$$(B)\ CaO+3Fe_3C=CaC_2+9Fe+CO.$$

The calcium carbid reacts with the iron of the bath and the oxygen dissolved therein to form calcium oxid, the carbon in nascent condition uniting with the iron to form carbid of iron.

$$(C)\ CaC_2+5Fe+(Fe+O)=CaO+2Fe_3C.$$

In the above formula (Fe+O) represents iron holding oxygen in solution.

It is my theory that the peculiar grain which is characteristic of crucible steel is due, not only to the action of nascent silicon on iron as is commonly believed, but to a large extent to the presence in the iron or steel of molecules of carbid of iron formed by the union of nascent carbon with iron. This would explain the necessity of providing carbon in combination with another element of such a nature that at the temperatures in question, the affinities are such as to permit the carbon and the iron to unite.

The CO produced by reactions A or B probably unites in part with iron according to the following formula:

$$(D)\ 4Fe+CO=Fe_3C+(Fe+O),$$

in which case again nascent carbon unites with the iron.

As the liquid metal at these temperatures will hold in solution only small quantities of oxygen, and part of the oxygen, in the form of CO is lost by rising out of the bath, it is clear that to obtain enough nascent carbon the oxygen at least must continuously be replaced. This is done by adding the Fe_3O_4 or Fe_2O_3 to the slag, which substances decompose at the high temperature into Fe_6O_7 and (Fe+O).

$$2Fe_3O_4+Fe=Fe_6O_7+(Fe+O).$$

This is the (Fe+O) referred to in reaction (C). It is the oxygen thus dissolved in the iron which appears at these high temperatures, to be a necessary active ingredient in my process.

As much of the carbon is lost in the form of CO (formulas A and B), the carbon must be replaced and this is done by adding the carbon as above described. If reaction A takes place, as I believe, then the presence of the added carbon undoubtedly hastens the formation of calcium carbid and thus speeds and cheapens the process.

When the process is operated on an acid hearth the course of the reactions is probably analogous to those above given, except that SiO_2, either that which is present in the lining or that which is present in the slag, or both takes the place of the CaO.

While it is known that protoxid of iron (FeO) is reduced by carbid of iron; it is also known that oxygen dissolved in iron will not react on carbid of iron. The affinity of iron and carbon increases as the temperature rises; carbid of iron being an endothermic body. The affinity of iron for oxygen, and of carbon for oxygen, decreases as the temperature rises, protoxid of iron and carbon monoxid being exothermic bodies. At a temperature which has not yet been exactly determined, the affinity (heat tension) of the carbid of iron overtakes that of protoxid of iron and of carbon monoxid; this temperature is, however, less than that at which my process is worked. Therefore, oxygen, iron and carbid of iron, can exist side by side, undisturbed, under the temperature conditions of my process.

At the temperature of my process the affinity between iron and carbon is greater than the affinity between carbon and oxygen dissolved in iron, and this fact explains the above reactions C and D.

When I speak in the claims of "heating the metal" I mean that the metal is heated to a temperature at which the result described will be attained, that is to say, as I understand the matter, to a temperature at which the oxygen dissolved in the iron will not decompose carbid of iron. When I speak in the claims of malleable iron, I refer to liquid iron which does not contain more than substantially 2% of carbon.

I claim:

1. The herein described process of improving the quality of malleable iron or steel by causing a metallic oxid and carbon to react at the same time thereon in a hearth furnace at a temperature at which oxygen dissolved in the iron will not decompose carbid of iron.

2. The herein described process of improving the quality of malleable iron or steel which comprises covering it in a hearth furnace with a slag containing a metallic oxid capable of supplying the metal with dissolved oxygen, heating the metal and adding carbon thereto, so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

3. The herein described process of improving the quality of malleable iron or steel which comprises covering it in a hearth furnace with a slag containing iron ore capable of supplying the metal with dissolved oxygen, heating the metal and adding carbon thereto so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

4. The herein described process of improving the quality of malleable iron or steel which comprises covering it in a hearth furnace with a slag containing a metallic oxid capable of supplying the metal with dissolved oxygen, heating the metal and adding carburite thereto, so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

5. The herein described process of improving the quality of malleable iron or steel which comprises carburizing the same, then covering it in a hearth furnace with a slag containing a metallic oxid capable of supplying the metal with dissolved oxygen, heating the metal and adding carbon thereto so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

6. The herein described process of improving the quality of malleable iron or steel which comprises carburizing the same, then covering it in a hearth furnace with a slag containing iron ore capable of supplying the metal with dissolved oxygen, heating the metal and adding carbon thereto so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

7. The herein described process of improving the quality of malleable iron or steel which comprises carburizing the same, then covering it in a hearth furnace with a slag containing a metallic oxid capable of supplying the metal with dissolved oxygen, heating the metal and adding carburite thereto so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

8. The herein described process of improving the quality of malleable iron or steel which comprises covering the iron in a basic hearth furnace with a non-oxygenous sulfur removing slag, heating the metal until the sulfur is eliminated, then removing the slag and with it the sulfur, then covering the metal on a hearth with a slag containing metallic oxid capable of supplying the metal with dissolved oxygen, heating the metal and adding carbon thereto so that the dissolved oxygen and carbon may be simultaneously active within the metal substantially as and for the purpose described.

9. The herein described process of improving the quality of malleable iron or steel which consists in covering the metal in an acid hearth furnace with a suitable slag and with iron ore capable of supplying the metal with dissolved oxygen, heating the metal and simultaneously adding carbon so that this oxygen and carbon may be simultaneously active within the metal, substantially as and for the purpose described.

10. The herein described process of improving the quality of iron or steel which consists in covering the metal in an acid hearth furnace with an acid slag consisting of lime, sand and manganese ore, and with iron ore capable of supplying the metal with dissolved oxygen and in heating the metal and simultaneously adding carbon thereto, so that the oxygen and carbon may be simultaneously active within the metal, substantially as and for the purpose described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

OTTO THALLNER. [L. S.]

Witnesses:

RICHARD SCHWETT,

THEODOR GEILENKIRCHEN.