PROCESS FOR THE PRODUCTION OF HIGH
ALLOYED STEELS

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In refining pig iron or other high carbon iron alloys with oxygen blown against the surface of the iron bath within a converter, crucible or similar container, it is known that the heat produced by the combustion of the impurities in the steel and of a certain amount of iron is more than sufficient to heat the melt to the temperature necessary for tapping off and to produce from the slag former's added a hot and reactive slag. So it is necessary to add to the bath scrap material or ore for cooling purposes, thereby avoiding too high an end temperature, protecting the refractory cladding and providing for unobjectionable casting properties of the steel produced. It has been recognized that with this process it is also possible to produce low alloy steels if the addition of scrap iron is reduced so that a somewhat higher temperature of the melt at the end of the blowing process is attained, whereby the excessive heat is used for melting deoxidation agents and alloying constituents, which are added to the refining receptor, or to the ladle after the end of the blowing process. In this manner now great quantities of low alloy steels are produced.

When it was tried to produce high quality steels with an average content of alloying elements rather a high end temperature of the bath had to be chosen to compensate for the reduction in temperature which is experienced after the blowing period on account of deoxidation, for the holding time necessary for the separation of the deoxidation products and for the addition and melting of the alloying additions. Therefore the quantity of cooling means had to be diminished or even omitted, and when blowing of chemically and/or physically cold iron carbon alloys and when producing of steels with a somewhat higher content in alloying elements, or when using cheaper low percent alloying means, one had to rely on the auxiliary means known per se which consists in adding to the bath prior to and/or during the blowing process such materials as carbon, silicon or aluminum and/or alloys of such materials, which dissolve in the bath and, by their combustion, supply the additional heat necessary for the oxygen refining process.

For the alloying additions containing alloying elements which do not have a lower affinity with respect to oxygen than iron, and therefore could not be added prior to or during the blowing process, with such a process at the end of the blowing process a high end temperature is necessary which severely reduces the life of the refractory cladding of the refining receptacle. However according to this process steels with a content in alloying elements of about 6 percent can still be produced. With steels which need only a low casting temperature the content in alloying elements can be increased, especially if high percent alloying means are used and if these are preheated.

On the other hand, however, alloying means, containing alloying elements with a greater affinity for oxygen than iron, can, prior to or during the blowing process, only be added to a restricted extent, because only at a low content in alloying elements the end temperature at the end of the blowing process, tolerable for the lining, is sufficiently high to shift the equilibrium between the iron bath and the slag in such a manner that an intolerable high quantity of alloying materials does not remain in the slag.

The present invention aims at providing a process for the production of high alloyed steels within a refining receptacle without external heating, for instance in a converter, crucible and the like, whereby the iron bath is refined by oxygen blown from above against the bath, and the inventive process consists essentially in that at least such alloying means, which contain alloying elements with a greater affinity with respect to oxygen than iron, and such heating materials with a greater affinity with respect to oxygen than iron and than the alloying elements are added to the bath in solid state in partial quantities, and that the bath between the single additions of the partial quantities is refined by the oxygen blown from above against the bath.

Due to the use of the heating materials having a greater affinity with respect to oxygen than the alloying elements contained in the alloying means, the addition of heating materials protects the alloying elements from excessive burning off and from transfer into the slag in spite of the addition of alloying elements having a greater affinity with respect to oxygen than iron. The addition in partial quantities prevents too great a heating of the bath so that the lining of the refining receptacle is protected and a long life period is guaranteed. The inventive process allows the temperature during the total process to be maintained more uniform and to avoid the temperature peaks which are dangerous for the lining. Additionally, the addition of alloying means in partial quantities prevents or greatly a cooling of the bath which would occur as a result of the addition of too great quantities of alloying means in solid state. Therefore, the process according to the invention is advantageously applicable if the total quantity of the alloying means to be added, which alloying means contain alloying elements with a greater affinity with respect to oxygen than iron, amounts to more than 15%, especially more than 25%, of the weight of the bath. The process according to the invention is of special advantage for the production of steels with a content of alloying elements, which have a greater affinity for oxygen than iron, of more than 10%, preferably more than 13%.

According to the invention there can be added as alloying additions FeCr, FeMn and the like and as heating materials Si, Al and the like and/or alloys of heating materials.

The partial quantities of alloying means and the partial quantities of heating materials, can, if desired, be added at different phases of the process. According to a preferred embodiment of the invention, however, the additions of alloying means and heating materials are made simultaneously, especially commonly (combined). Alloying means and heating materials can be added to the bath in form of a single alloy, however, for instance in form of FeCr with high Si-content.

It is advantageous to distribute the additions of the partial quantities with reference to the process time in such a manner that the partial quantity of the heating materials following next is added at a content of the bath in heating materials which is just sufficient to protect the alloying elements, for instance Cr, from excessive burning off and transfer into the slag. Thereby, the requirements, namely to avoid excessive heating of the bath and simultaneously to retain the alloying elements within the bath, are best met. Preferably the heating materials are added in such a quantity that the heat supplied to the bath by oxidation of the heating materials corresponds to the heat consumed by the alloying process.

According to the invention the ratio of the added alloying means and the heating materials is selected so that before the addition of the partial quantity following next
between two blowing periods the temperature of the melt does not exceed 1750° C., but preferably is 100 to 250° C. higher than the liquidus-temperature of the alloy present in the melt. Then, the ratio of alloying elements and heating materials in each partial quantity, and the quantity of oxygen blown onto the bath after the addition of the partial quantity, can be selected so that at least 80%, preferably more than 90%, of the alloying elements added are found in the finished steel. As the temperatures during the process it seems appropriate to select not too large partial quantities. Therefore, according to the invention, the single partial quantities of the alloying means are so dimensioned that the single increase in alloying elements in the melt amounts to not more than 10%, preferably to about 5%. During the additions of the partial quantities of alloying means and heating materials the blowing of oxygen onto the bath can be interrupted to avoid burning off of these materials during their addition.

For the production of steels containing alloying elements with a greater affinity and alloying elements with a lower affinity, it is advantageous for the refining process a bath can be utilized which already contains the alloying elements with a lower affinity with respect to oxygen than iron. These alloying elements with a lower affinity with respect to oxygen than iron can be added to the melt within the refining receptacle or into the refining receptacle prior to filling the receptacle with the melt. However, refining can also be started using an iron bath with a content in alloying elements with a greater affinity with respect to oxygen than iron, for instance by adding to the bath within the refining receptacle the first partial quantity of at least the alloying means prior to the beginning of the refining process.

According to a special advantage of the invention, prior to each addition of a partial quantity of alloying means, the slag is completely or partially removed or reduction means are thrown onto the slag. Thereby, according to the invention, it can be proceeded so that, prior to the addition of a partial quantity, the bath, essentially free of slag, is transferred into a ladle or the like, the slag is removed from the refining receptacle and the bath is transferred into the refining receptacle, whereby the addition of the partial quantity is made into the ladle or the refining receptacle.

Particularly when refining of iron baths rich in phosphorus, according to the invention, prior to the addition of the first partial quantity of alloying means, these can be refined, with an addition of heating materials if desired, until a low carbon and phosphorus content of the bath is attained. The use of the inventive process is of special advantage when producing extremely soft CrNi steels with less than 0.05% C., preferably 0.03% C., maximally.

**Example**

A crucible was charged with 20,300 kg. pig iron and 2,900 kg. nickel, the original Si-content of the pig iron of 0.10% was increased to 0.6% by addition of FeSi-alloy. Within 16 minutes and 35 seconds, under normal blowing conditions, the melt was blown down to 0.93% C. and 0.21% Mn. The bath temperature was 1750° C. For complete removal of the slag the charge was tilted through the tapping hole. During this procedure the addition of the first partial quantity of 2,500 kg. FeCr was added in the ladle. The slag was dumped out of the crucible whereafter the melt was transferred to the crucible. It was blown for 1 minute and 15 seconds. Then the slag was removed and the second partial quantity of 2,700 kg. FeCr was given to the bath within the crucible. A Simplex FeCr with a Si-content of approximately 6% was used. Thereby, by calculation, the bath contained after each addition approximately 0.5% Si. The melt was blown to heat within 1 minute 15 seconds; the temperature measured was 1710° C. Now again it was tilted through the tapping hole, whereby the addition of the third partial quantity of 2,300 kg. FeCr was given to the pan. After transferring it was blown to heat again; the blowing period lasted 2 minutes. The temperature was at 1700° C., analysis of the melt at this moment showed 0.02% C.; 0.19% Mn; 0.32% Si; 10.96% Ni; 13.82% Cr; 0.009% P; 0.014% S. In the same manner a further partial quantity of 1,200 kg. FeCr and 20 kg. FeSi was now introduced into the melt; it was blown for 1 minute and 30 seconds; a temperature of 1705° C. was attained. An intermediate analysis showed: 0.025% C; 0.16% Mn; 0.31% Si; 10.47% Ni; 15.72% Cr; 0.010% P; 0.014% S. After addition of the remaining 1,000 kg. FeCr a temperature of 1560° C. was determined. After resting the crucible for 12 minutes the melt was tilted, thereby adding 280 kg. FeSi carbruf, then it is a ferro-manganese having an extremely low carbon content, in most cases below 0.1 percent, and 200 kg. FeSi of 75%. After the melt had stood for 8 minutes—whereafter the melt had a temperature of 1420° C.—measured with the Pyropoint, an optical bath thermometer, was directly cast. Analysis of the melt showed: 0.03% C; 0.98% Si; 1.86% Mn; 9.96% Ni; 17.42% Cr; 0.010% P; 0.014% S. The yield in chromium was 85%. By a reductive treatment of the melt the yield in Cr can be further increased.

**What we claim is:**

1. In a process for the production of high alloy steels with a content of alloying elements of at least 10% in a refining receptacle, wherein the metal bath is refined by oxygen blown from above against the bath, the improvement which comprises introducing directly into said metal bath in increments, at least such alloying elements, which contain alloying elements with a greater affinity with respect to oxygen than iron, and also introducing directly into said metal bath such heating materials with a greater affinity with respect to oxygen than iron and then the alloying elements in solid state, and refining said metal bath between the single additions of the increments by oxygen blown from above against said metal bath, the increments of the alloying means and of the heating materials being, with reference to the process time, distributed in such a manner that the partial quantity of the heating materials following next is added to a content of the bath in heating materials which is just sufficient to protect the alloying elements from excessive burning off and transfused into the slag and the increments of the heating materials with respect to the increments of the alloying means being selected so that at the end of the refining process at least 80% of the alloying means added are found in the steel, and the ratio of the alloying means and the heating materials added being further selected so that, before the addition of the next increment, the temperature of the melt does not exceed 1750° C., but is 100 to 250° C. higher than the liquidus-temperature of the molten alloy and recovering the high alloy steel, the entire procedure from adding of said alloying and said heating materials through said recovering of the high alloy steel being carried out in the absence of external heating.

2. Process according to claim 1, wherein at the start of the process said metal bath contains alloying elements with a greater affinity with respect to oxygen than iron as a result of adding the first increment of at least the alloying means, with said refining receptacle prior to the beginning of the refining process.

3. Process according to claim 1, wherein, while adding said increments of alloying means and heating materials, blowing of oxygen against the bath is interrupted.

4. Process according to claim 1, wherein, prior to each addition of at least one increment of alloying means, the slag is, at least partially, removed.

5. Process according to claim 1, wherein, prior to each addition of an increment of alloying means, reduction means are strewn onto the slag.
6. Process according to claim 1, wherein, prior to the addition of the first increment of alloying means, refining is carried out until a low carbon and phosphorus content of the bath is attained.

7. Process according to claim 1 wherein, prior to the addition of an increment, said metal bath, essentially free of slag, is transferred into a vessel, said slag is removed from the refining receptacle and said metal bath is retransferred into the refining receptacle, and wherein the addition of an increment is made into the refining receptacle.

8. Process according to claim 1 wherein said alloying means includes alloys selected from the group consisting of ferro-manganese and ferro-chrome and wherein said heating materials includes elements selected from the group consisting of silicon, aluminum and alloys thereof.

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BENJAMIN HENKIN, Primary Examiner.