D.C. ARC FURNACE FOR STEELMAKING

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ABSTRACT

A system for producing steel comprises a d-c arc furnace having at least one water-cooled anode connectable to the d-c source and effective after melting has progressed to generate an arc between the melt and a cathode juxtaposed therewith. A melting anode is connectable to the d-c source initially and is pressed against the mass to be melted for the initial melting and is movable to follow the decrease in level of this mass as the melting progresses. Switches disconnect the melting anode and connect the process anode to the source.

8 Claims, 12 Drawing Figures
D.C. ARC FURNACE FOR STEELMAKING

FIELD OF THE INVENTION

This invention relates to a method of and a DC arc furnace for steelmaking.

BACKGROUND OF THE INVENTION

A method of making steel with three-phase electric current is known in which the electric arcs burn between the carbon electrodes and ferrous materials, i.e., melted steel. During melting the voltage and the current vary within a given range, but the whole process of steelmaking from the beginning of the melting till the end of the refining takes place without changes in the way the current is supplied to the furnace. This method has been applied in the three-phase arc furnace of He-rout, where three carbon electrodes are connected with the respective electric phases.

There is yet another method of steelmaking with two- or three-phase current, where the electric arc burns between carbon electrodes, and the iron materials, i.e., the molten steel, are excluded from the electric circuit. The Sasso arc furnace is based on this method, the current being supplied across two or three carbon electrodes. This furnace has limited application, mainly for casting nonferrous metals.

There exists a method, according to which the current is brought in through the bottom of the furnace directly to the iron materials, i.e., the molten steel, the latter being included in the electric circuit. A disadvantage of this method is the fact that it has unsatisfactory operation reliability. Arc furnaces based on this method have been tried, but have not found any industrial application.

It is a well known fact that from the point of view of electrothermics the DC electric arc has considerable advantages over an alternating current arc. With the latter, the same quantities of heat are liberated at the two poles, while with the DC electric arc the heat liberated at the anode is several times greater than the heat liberated at the cathode. Moreover, a DC electric arc is more stable than an AC arc.

In spite of this advantage, however, nowadays electric steel is not produced in DC furnaces as the conventional physical arrangement of an AC electric arc furnaces doesn’t provide any advantage when DC is substituted. Another important shortcoming is the fact that in today’s high-power and ultrahigh-power furnaces the connection of the DC source with the iron material, i.e., the molten steel, cannot be accomplished by the method by which the current is directly connected through the furnace bottom with the iron materials, which are included in the electric circuit. In the present specification the term “iron materials” covers all metal materials which are fed into the arc furnaces, such as steel scrap (incl. high-alloy scrap), sponge iron, metalized pellets, ferrous alloys, alloying metals, etc.

OBJECT OF THE INVENTION

The object of this invention is to provide a new method of steelmaking with direct current, where the advantages of the DC arc will be used, as well as a DC arc furnace for steelmaking, where the positive pole of the DC electric source is stably brought to the iron materials during the melting and to the melted steel during the metallurgical processes (oxidation, alloying, refining, etc.), the operation of that furnace being reliable and causing no difficulties in operation.

This object is achieved, according to the method of steelmaking with direct current, the electric arcs being ignited (burned) by means of one or more movable carbon cathodes, connected with the negative poles of the DC source throughout the whole heat, and one or more movable melting anodes, connected with the positive poles of the DC source and closely pressed to the solid iron materials. The burning takes place between the movable carbon cathodes and the iron materials, and later on between the cathodes and the molten steel. After the bottom of the furnace is covered with molten steel the positive poles of the DC source are connected with one or more metallic water-cooled process anodes, which are in contact with the melted steel in such a way, that till the end of the heat the arcs burn only between the movable carbon cathodes and the melted steel.

The term “carbon cathodes” stands for carbon electrodes that carry the current into the furnace space, which are connected with the negative poles of the DC sources.

The term “movable melting anodes” identifies movable electrodes which, during the melting, are connected with the positive poles of the DC sources, which maintain constant electric contact with the iron materials.

The metallic water-cooled electrodes, which are connected with the positive poles of the DC sources during the metallurgical processes (oxidation, alloying, refining, etc.) and maintain constant electric contact with the molten steel, are called “metallic water-cooled process anodes.”

The arc furnace to carry out the method of this invention consists of a bottom, walls and a roof. One or more movable carbon cathodes, each fitted with a moving device, are inserted in holes in the roof. The cathodes are connected by means of switches with the negative poles of the DC sources.

In holes situated above the furnace door sole, one or more movable melting anodes are inserted into the furnace space, which are fitted with a device to press them against the iron materials. These anodes are connected by means of switches with the positive poles of the DC sources.

In respect of material and design, the melting anodes can be made in conventional ways (carbon electrodes, metallic water-cooled electrodes, or metallic water-cooled electrodes with suitable electroconductive caps).

The furnace is equipped with metallic water-cooled process anodes to contact the molten steel, which are connected with the positive poles of the DC sources. The metallic water-cooled process anodes are immovable and are built into the walls in such manner that their front part is below the level of the door sole and their water-cooled part is inside the walls.

It is worthwhile to use an arc furnace, the metallic water-cooled process anodes of which are movable. They are inserted into the furnace space through holes situated above the door sole and are fitted with an operating mechanism to make them move forth until their front part reaches a level below the door sole. They can be moved back at least till their front part is hidden in the openings in the furnace walls.
The movable melting anodes and the metallic water-cooled process anodes are electrically insulated from the furnace shell or are in parallel therewith and thus are connected with the furnace shell. The movable carbon cathodes, as well as the movable melting anodes made of carbon material have a protective coating to prevent oxidation of their side surface.

A considerable advantage of the method of this invention is the substantial reduction of electrode consumption, the consumption of carbon material at the cathode being considerably smaller than that of an electrode in the AC arc and many times smaller than that at the anode. Moreover, as a result of the generation of the greater part of the heat in the molten steel, the temperatures of the walls and of the roof can be much lower than that of the metal, which makes their endurance longer and cuts down the covering materials investments. The more beneficial distribution of heat in the DC arc compensates for the electric losses in the rectifiers and saves electric power.

In the DC arc furnace the electromagnetic asymmetry of the system, available in the three-phase AC He-roult furnaces, are avoided. In the arc furnaces, based on the method of the present invention, one cathode gives completely symmetrical heat (thermal) loading of the walls. An important advantage of this invention is the fact that the electrical regime of the DC arc is much steadier than that of the AC arc, the burning of the DC arc being accompanied by considerably less noise, which is within acceptable limits.

**BRIEF DESCRIPTION OF THE DRAWING**

The furnace, according to the invention, is illustrated in the accompanying drawing. In the drawing:

**FIG. 1** is a vertical cross-sectional view along the line A—A of an arc furnace with one movable melting anode, inserted into the furnace space through the furnace roof during the melting of iron materials;

**FIG. 2** is a horizontal cross-sectional view along the line B—B of the arc furnace in FIG. 1;

**FIG. 3** is a vertical cross-sectional view along the line A—A of the furnace in FIG. 1 after melting of the iron materials during the metallurgical processes;

**FIG. 4** is a vertical cross-sectional view along the line A—A of an arc furnace with two movable anodes, inserted in the furnace space through openings situated in the furnace walls and four metallic water-cooled process anodes built horizontally into in the furnace wall;

**FIG. 5** is a top view of the furnace of FIG. 4 during the melting;

**FIG. 6** is a vertical cross-sectional view along the line A—A of the furnace in FIG. 4 during the metallurgical processes;

**FIG. 7** is a cross-sectional view along the line A—A of an arc furnace with three movable melting anodes and three metallic water-cooled process anodes;

**FIG. 8** is a top view of the furnace in FIG. 7;

**FIG. 9** is a cross-sectional view along the line A—A of the furnace in FIG. 7 during the metallurgical processes;

**FIG. 10** shows an arc furnace with three movable carbon cathodes inserted through the furnace roof and three movable metallic water-cooled process anodes during the metallurgical processes;

**FIG. 11** is a top view of the furnace in FIG. 10; and

**FIG. 12** shows a circuit of connecting the cathodes and anodes to the DC sources.

**SPECIFIC DESCRIPTION**

The DC arc furnace for steelmaking, shown in FIG. 1, has one movable carbon cathode 3, inserted in the furnace space 7 through the roof 6. By means of an actuating mechanism 19, the movable carbon cathode can be moved up- and downwards. Into the furnace space 7, through the roof 6 is inserted one melting anode 2, too, which is connected with device 12 to move it up- and downwards, as well as to press it to the iron materials 13 with a constant force. Into the walls 5 water-cooled process anodes 1 are built, situated at an angle, so that their front part is at a level below the door sole 8 and above the bottom 4 of the furnace. The outer part of the process anodes 1, situated in the walls 5 of the furnace, is water-cooled. Besides, at the entrance of the process anodes 1 into the furnace body water-cooled jackets 15 are installed.

The negative pole of the DC source 10 is connected through switch 18 with the movable carbon cathode 3, and the positive pole of the DC source can be connected through switch 16 with the movable melting anode 2 and through switch 17 with the three water-cooled metallic process anodes; the latter are situated at an angle of 120° one to the other (FIG. 2).

The method of this invention is performed in the following manner. The furnace is charged with iron materials 13. The switches 16 and 18 are turned on, switch 17 remains turned off. The melting anode 2 is moved downwards by means of an actuating mechanism 12 and is pressed with a constant force against the iron materials 13. Then begins the downward movement of the carbon electrode 3 until it reaches the iron materials 13 and an electric arc 9 is ignited. Roughly, the melting is carried out in the conventional way — the movable carbon cathode 3 forms a hole in the iron materials 13 and comes near the furnace bottom 4. In the meantime melted steel 14 has been formed below it. As the melting proceeds, the quantity of melted steel 14 increases at the same time the iron materials 13 gradually get lower and lower. By means of the actuating mechanism 12 the movable melting anode 2 follows the lowering of the iron materials 13 and is constantly in an effective electric contact with them. A burning of long duration of the arc at the melting anode 2 is not at all admissible. Under the action of the "electromagnetic wind" the arc is curved to the opposite direction of the place of contact of the melting anode. As can be seen from FIG. 1 and FIG. 2, more iron materials 13 are melted at the door and less at the melting anode 2.

Depending on the particular conditions, the furnace can be loaded (charged) with iron materials 13 one, two or more times.

The melting is performed in described manner until there is enough melted steel 14 in the furnace, so that its level is higher than the contacting front part of the process anodes 1. Then the electric connection between the positive pole of the DC source 10 and the melting anode 2 breaks up and by means of actuating mechanism 12 the melting anode 2 is lifted above the furnace roof 6, the holes in the roof being closed in an appropriate way (FIG. 3).

By means of switch 17 the positive pole of the DC source 90 is connected with the three process anodes 1, which are in parallel. Due to the symmetrical dispo-
sition of the process anodes 1, the ignited arc 9 is now burning perpendicularly to the melted steel 14, whereupon the heat loading of the walls 5 is uniform.

The required metallurgical processes being performed and having attained the desired chemical composition and the necessary temperature of the steel 14, the current is switched off and the steel 14 is tapped.

The furnace in FIG. 4 has two movable melting anodes 2, which are inserted into the furnace space 7 through openings situated in the walls at a level higher than the door sole 8. The melting anodes 2 are outfitted with an actuating mechanism 12 to move them inwardly and outwardly, as well as to press them with a constant force against the iron materials 13. The furnace has four metallic water-cooled process anodes 1, which are horizontally built into the furnace walls 5.

The two melting anodes 2 are situated symmetrically at an angle of 180° and are at the same time inclined (see FIG. 5). As shown in FIG. 6 the anodes are situated at a level, higher than the door sole 8. The process anodes are situated symmetrically at an angle of 90° one to the other. Each melting anode 2 can be connected with the positive pole of the DC source 10 by means of a separate switch 16, and each process anode 1 — by means of a separate switch 17.

The system operates in a manner similar to that described above. During the melting the movable carbon cathode 8 and the two movable melting anodes 2 are connected with the DC source. At this stage the four process anodes 1 shouldn't be connected with the DC source. Towards the end of the melting the current in the melting anodes 2 is turned off by means of the switches 16, the melting anodes 2 are lifted up at least until they are hidden in the furnace wall 5. Then the four process anodes 1 are connected with the positive pole of the DC source 10 by means of the switches 17, after which the metallurgical processes are performed.

All anodes (melting anodes 2 and process anodes 1) have their own separate switches 16 and 17, which makes it possible, by switching on and off of particular anodes, to direct the electric arc 9 in the desired direction. This direction is contrary to the connection of the positive pole of the DC source 10 with the iron materials 13 or the melted steel 14.

The furnace shown in FIG. 7 has one movable carbon cathode 3, three movable melting anodes 2, fitted with actuating mechanisms 12 and three metallic water-cooled process anodes 11, fitted with actuating mechanisms 20. The melting anodes 2 and the process anodes 11 are situated into the furnace space 7 through one and the same openings. These three openings are situated in the furnace walls 5 at a level higher than the door sole 8.

FIGS. 7 and 8 show the connection of the melting anodes 2 with the positive pole of the DC source 10 by means of switch 16. In the same Figures the process anodes 11 and the switch 17 are not shown.

Towards the end of the melting the current is turned off, the melting anodes 2 are driven out of the furnace shell; through the same openings the three movable metallic water-cooled process anodes 11 are inserted into the furnace space 7 by means of actuating mechanism 20 to such an extent, that their front end 15 is below the level of the door sole 8 and they are sufficiently immersed into the melted steel 14. Then the process anodes 11 are connected with the DC source 10 by means of switch 17 after which the metallurgical processes are performed.

In FIG. 9 the melting anodes 2 and the switch 16 are not shown.

The furnace shown in FIG. 10 has three movable carbon cathodes 3, which are inserted into the furnace space 7 through three holes in the roof 6. In the furnace walls there are three openings at a level higher than that of the door sole 8, through which the movable melting anodes 2 and the movable water-cooled process anodes 11 are inserted in succession. The DC sources 10 are used, each of them supplying one carbon cathode 3 and one melting anode 2 until melted steel is produced, after which they are connected with a process anode 11 each as well.

FIG. 11 shows the connection of cathodes 3 and anodes 11. Cathode 3 and anode 11, which are supplied by one and the same DC source 10, are situated one opposite the other. In this case the electric arcs 9 curve to the center of the furnace, as shown in FIG. 10.

The melting is performed as with the furnace in FIG. 7.

FIG. 12 shows a circuit for connecting the cathodes and the anodes. The furnace has three movable carbon cathodes 3, three melting anodes 2 and three process anodes 1, 11. In the Figure anodes 1, 2 and 11 are used singly and the three types of anodes are not used simultaneously.

It is evident from FIG. 12 that every negative pole of the DC sources 10 can be connected with every one or several of the cathodes. The same applies to the positive poles of the DC source 10 and to the anodes 1, 2, 11 as well.

As the diagram shows, there are several possibilities for directing one or more electric arc 10 in the required direction. With the conventional DC sources, which have a dropping voltage-amperage characteristics, to connect more cathodes to one DC source is not worthwhile as one DC source of this type cannot keep more than one arc burning. This doesn't apply to the anodes where every combination of their inclusion in circuit is acceptable.

With some DC sources (those with constant characteristics, for example) it is possible to connect the negative pole of a DC source to one, two or more cathodes. In order to perform the melting, the switches 18a, 18b, 18c and the switches 16a, 16b, . . . 16i are turned on. The electric arcs at all cathodes (3a, 3b, 3c) are directed vertically. After the iron materials in the centre of the furnace have been melted, switches 16a, 16c, 16e, 16f, 16g and 16h are turned off. Then the electric arcs are directed towards the furnace walls so that melting is intensified in those areas.

At the end of the melting, switches 16b, 16d and 16g are turned off the melting anodes 2a, 2b, 2c are drawn out of the furnace, the process anodes 11a, 11b, 11c being immersed in the molten steel. Switches 17a, 17e, 17i are turned on and the arcs are directed towards the centre of the furnace. In this way burning of the walls during the metallurgical processes is prevented.

What we claim is:

1. An apparatus for making steel by an arc process, comprising:
   a furnace having a hearth and a substantially closed top provided with at least one opening;
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a carbon cathode extending through said opening and provided with means enabling displacement of said carbon cathode relative to said hearth;
a water-cooled process anode received in said furnace at a level above the bottom of said hearth and adapted to contact a melt of steel upon the formation thereof;
at least one melting anode movably extending into said furnace and provided with means for pressing said melting anode against a mass of ferrous material in said furnace on said hearth and enabling said melting anode to follow the decrease in level of said material upon the smelting thereof;
a direct-current source having a negative terminal connected to said cathode;
first switch means between the positive terminal of said source and said melting anode for initially connecting said melting anode with said source whereby electric current flows through said material between said cathode and said melting anode to smelt said material and form a pool of molten steel on said hearth; and
second switch means between said positive terminal and said process anode and operable alternately with said first switch means for connecting said process anode to said source to enable an electric current to pass through the pool of molten steel between said process anode and said cathode.

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2. The apparatus defined in claim 1 wherein said furnace has a door with a sill and said process electrode is built into a wall of said furnace at a location below said sill and is fixed in said wall.
3. The apparatus defined in claim 1 wherein said process anode has a water-cooled portion received in a wall of said furnace.
4. The apparatus defined in claim 1 wherein said furnace has a door with a sill, said process anode being movably mounted in a wall of said furnace and having a lower end disposed below said sill in a fully inserted position of said process anode.
5. The apparatus defined in claim 1 wherein said furnace has a shell, further comprising means for electrically insulating said anodes from said shell.
6. The apparatus defined in claim 1 wherein said furnace has a shell and said anodes are connected in parallel and are electrically connected with said shell.
7. The apparatus defined in claim 1 wherein said cathode has a protective coating preventing oxidation of its flanks.
8. The apparatus defined in claim 1 wherein said melting anode is composed of carbon and has a protective coating along its flanks.