This invention relates to an improved method for desulphurizing molten pig iron by adding a desulphurizing agent to molten pig iron bath contained in a ladle and agitating said bath with an impeller placed in said bath, wherein downward streams are caused in said bath by inserting one or more guide plates in the upper portion of the bath thereby to draw the desulphurizing agent into the downward streams and an improved rate of desulphurization is obtained even when the rotation speed of said impeller is lower than when no guide plate is employed.

7 Claims, 7 Drawing Figures
PROCESS FOR DESULPHURIZATION OF MOLTEN PIG IRON

BACKGROUND OF THE INVENTION

Various techniques have heretofore been developed by way of desulphurizing molten pig iron. However, all of these techniques are the same in the fundamental idea, that is to say, they all seek effective method for mixing desulphurizing agents with molten pig iron so as to obtain an improved rate of desulphurization per unit time. These conventional techniques are represented by the following: (a) The process in which a desulphurizing agent is introduced in a ladle and then molten pig iron is poured into the ladle; (b) the process in which a desulphurizing agent is introduced onto the surface of a molten iron bath in a ladle and then the ladle is rocked and shaken; (c) the process in which molten iron and desulphurizing agent are caused to flow in opposite directions to each other; (d) the process in which the interface between desulphurizing agent and molten iron is agitated; and (e) the process in which a vortex is created by the rotation of an impeller on the surface of the bath in order to have the desulphurizing agent drawn into said vortex.

However, these prior art processes have shortcomings respectively. The processes (a) and (c) are defective in the rate of desulphurization; the process (b) is disadvantageous in respect of equipment cost and operation cost; the process (d) is somewhat inferior to (e) in desulphurization rate per unit time, though it is considerably economical in operating cost and higher in desulfurization efficiency than (a) and (c); and the process (e), though excellent in desulphurization efficiency, is defective in that the refractories constituting the ladle and impeller are damaged severely owing to the high rate of rotation of the impeller, that the actual capacity of the treating ladle is reduced because of the partial swell of the bath surface and that expensive power equipment is required for rotating the impeller. As inventions disclosing methods corresponding to the process (e), there are Japanese Patent Specifications No. 123436/67, No. 32336/70 and No. 31054/70, etc. As is clearly seen from the claims and detailed descriptions in the specifications of these applications, there is an inevitable condition that “a vortex must be created and desulphurizing agents must be drawn into the vortex,” regardless of a very wide range of numerical limitations disclosed in each of said inventions with respect to the size, the depth of immersion, the effective cross-sectional area ratio and the rotation speed of the impeller, etc.

The present invention has been worked out through a series of researches directed to overcoming the above-stated drawbacks of the prior art desulfurization processes.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a process for removing sulphur from molten pig iron produced by blast furnaces, electric furnaces, cupolas, etc. To attain this object, a ladle containing molten pig iron poured thereinto is settled in place in a desulphurizing apparatus (FIG. 5), a predetermined quantity of a desulphurizing agent is added into the ladle, streams mostly flowing horizontally in one direction are created in the molten iron bath by rotating the impeller placed in the bath, one or more guide plates having a width equal to one-fourth to two-thirds of the radius of the ladle are immersed into the upper part of the bath to a depth of one-fourth to three-fourths of the distance between the surface of the static bath and the upper surface of the impeller in the bath, thereby to create downward streams in the bath into which the desulfurizing agent is drawn.

It is the main object of the present invention to obtain an excellent rate of desulfurization by providing an impeller plus a guide plate in contrast to the prior methods devoid of a guide plate even when the impeller is immersed shallowly and the speed of rotation thereof is low. As a result, the possibility of wear and breakage of the impeller is lessened, the cost of power and equipment required for desulfurization is reduced and the amount of molten iron to be treated in a vessel can be made equal to the nominal capacity of the vessel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view showing through a water model how the bath is agitated when no guide plate is employed;

FIG. 2 is a schematic view showing same when a guide plate is employed;

FIGS. 3 and 4 are schematic views showing how the desulphurizing agent is drawn into molten pig iron;

FIGS. 5 and 6 show different forms of apparatuses for carrying out the desulphurization process according to this invention; and

FIG. 7 is a comparative graph showing desulfurization rates in the presence of a guide plate and in the absence of same.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention presents a desulfurization process based on addition of a desulfurizing agent to molten pig iron contained in a ladle characterized in that streams mostly flowing horizontally in one direction are created in the molten pig iron bath by an impeller placed in the bath, downward streams are created in the bath by immersing one or more guide plates in the upper part of said bath and the desulfurizing agent is thereby drawn into said downward stream.

Taking treatment in a ladle as an example, the above-cited stream mostly flowing horizontally in one direction means a circulating current of molten pig iron caused to flow in one direction along the inner periphery of the ladle as a result of the continuous and one-way rotation of the impeller. Strictly speaking, the movements of the molten iron in the ladle include also other streams conditioned by the rotation speed of the impeller and the depth of immersion thereof such as those advancing straight toward the wall of the ladle from the central portion and those rising upward along the wall of the ladle and then moving toward the center of the ladle, the latter phenomenon being generally seen near the surface of the bath. However, what matters most in the present invention is the above-stated horizontally flowing current.

In the case of the present invention, the impeller placed in the bath is required only to cause the molten iron to flow mainly in a definite direction. Also, the contact and reaction between the molten iron and the desulfurizing agent are rapidly effected because the desulfurizing agent is drawn into the violent downward streams created in the molten iron by the inser-
tion of the guide plate thereinto. Therefore, shallower immersion and lower rotation speed of the impeller than in the case of the prior art process (e) can produce satisfactory results.

The size, depth of immersion and relative position of the guide plate constituting a characteristic feature of the present invention are as follows:

- **Width of the guide plate** — between one-fourth and two-thirds of the radius of the ladle
- **Depth of immersion of same** — between one-fourth and three-fourths of the distance between the surface of static bath and the upper surface of the impeller
- **Relative position of same** — a portion of the guide plate should preferably be located directly above the locus described by the ends of the impeller

The size, shape, depth of immersion, etc. of the impeller need not be particularly defined, since it is required only to cause the molten iron to flow in a definite direction as mentioned earlier.

Since the chief objects of the present invention are to reduce the possibilities of the impeller being worn and broken, to lessen the cost of power equipment for desulphurization and to make it possible to treat increased amount of molten iron in a given vessel, the essential conditions required of the prior art process (e) are alien to the present invention.

In describing the present invention in greater detail, the conventional process employing an impeller only and the present invention employing both an impeller and a guide plate will be compared through water model tests. This will serve to give a better understanding of the contents of the present invention and differences thereof with the prior art.

**FIG. 1** schematically shows various forms of water model tests conducted by using only a single impeller. The tests were conducted by changing the speed of rotation and the depth of immersion of the impeller. The dotted lines in FIG. 1 indicate the static liquid level. Chips of foamed styrene were used as a desulphurizing agent. The condition shown in FIG. 1a-1 may be considered as representing the operating conditions of conventional processes. In this case, the desulphurizing agent 2 is circulated in the directions indicated by the arrows, showing the molten pig iron 3 and the desulphurizing agent 2 contacted in a very good condition. When the impeller 1 was set such that its depth of immersion was reduced while maintaining the speed of rotation unchanged, the tendency of the desulphurizing agent 2 being drawn into the circulating molten iron declined. When the impeller 2 was set at a shallower level, ring-shaped swelling waves were formed around the impeller 2 (FIG. 1a-2), pushing the desulphurizing agent 2 entirely toward the wall of the ladle 4. When the impeller 2 was further lifted until its upper surface appeared above the surface of the water, ring-shaped waves swelled further causing part thereof to scatter in the form of water drops in the circumferential direction. When the impeller 2 was set such that a portion thereof completely appeared above the surface of static water, as shown in FIG. 1a-3, almost all of the waves scattered in drops and a portion of the desulphurizing agent was exposed to the falling drops and driven into the mass of water.

When the position of the impeller 1 was returned to the level shown in FIG. 1a-1 and similar tests were conducted with the speed of rotation of the impeller 1 dropped to 80–90%, the results obtained were as shown in b-1, b-2 and b-3. In the case of b-1, the desulphurizing agent went into the vortex but gathered at the bottom of the vortex. When the depth of immersion of the impeller 1 was reduced to the level shown in b-2, the height of waves formed above the impeller was far lower than in the case of a-2 but the desulphurizing agent 2 was pushed toward and was floating near the wall of the vessel 4 as in the case of a-2. Even when the impeller was set such that a portion thereof appeared above the static bath level, the situation in this case was like that shown in b-3 with almost no scattering of the liquid being observed, though the desulphurizing agent 2 was found cornered near the wall of the vessel 4. FIG. 2 schematically shows various forms of water model tests conducted under conditions respectively corresponding to those shown in FIG. 1, utilization of the guide plate which features the present invention being the only difference.

When the guide plate 5 was added to the case of FIG. 1a-1 which corresponds to the operating conditions of the prior art processes, the form of the vortex was changed to some extent as shown in FIG. 2a'-1 but no change was observed in the effect of drawing the desulphurizing agent 2 into the vortex. When the depth of immersion of the impeller 1 was gradually reduced with the speed of its rotation maintained unchanged, the phenomenon of the desulphurizing agent 2 being drawn into the vortex ceased to occur when the impeller reached a certain depth. In the condition of FIG. 2a'-2 which corresponds to FIG. 1a-2, the height of the ring-shaped waves was lower but the desulphurizing agent was found cornered near the wall of the vessel 4. In the case of FIG. 2a'-3 where the position of the impeller 1 was similar to that of FIG. 1a-3, the height of waves was lower to some extent but violent scattering of water drops was observed.

When the position of the impeller 1 was lowered again and the speed of its rotation was decreased to 80–90%, a marked change in situation was observed as compared with the case of FIG. 1b-1. While, in FIG. 1b-1, the desulphurizing agent 2 gathered at the bottom of the vortex, said agent was this time distributed in suspension in the molten iron, instead of gathering, as shown in b-1. This condition remained unchanged even when the impeller 1 was placed shallower. In the case of FIG. 2b'-2 which corresponds to FIG. 1b-2, the phenomenon of the desulphurizing agent being drawn into the vortex still occurred. In this case, the ring-shaped swelling waves which were seen above the impeller in FIG. 1b-2 completely disappeared because of the presence of the guide plate 5 and a small vortex was created around the shaft of the impeller. When the impeller 1 was placed shallower, ring-shaped waves were produced and the desulphurizing agent 2 was pushed toward the wall of the vessel 4, instead of being drawn into the bath. When the impeller 1 was placed such that its upper surface appeared above the water surface, there was little change from the case of FIG. 1b-3 excepting that the height of waves became lower, resulting in the situation as shown in FIG. 2b'-3.

As for the guide plate 5, its width should preferably be nearly equal to the diameter of the impeller 1 and its preferable depth of immersion is such that the lower end thereof does not reach the lower end of the impeller 1. Desired effect can be obtained with a single guide plate when the impeller 1 is rotated in one definite di-
rection but a plurality of guide plates may also be used.

It will thus be seen from the above comparison between Fig. 1 and Fig. 2 that the favorable condition of Fig. 1b–1 obtained when using the impeller alone can be obtained when the guide plate is added, not only in the case of Fig. 2b–1 but also in the case of Fig. 2b–2. Since deeper immersion and greater speed of rotation of the impeller 1 require more horse power for the rotation of the impeller 1 and since increased horse power brings about increased wear of the impeller 1, it is evident that the processes of the present invention as shown in Figs. 2b–1 and 2b–2 wherein the impeller is rotated at a slower speed and the process featuring shallower immersion of the impeller as in the case of Fig. 2b–2 are far more advantageous than the prior art processes.

The following is the reason why the provision of the guide plate 5 facilitates the introduction of the desulphurizing agent 2 into the molten pig iron 3 even at a low-speed rotation of the impeller 1.

If the molten iron is stirred at a relatively low speed in the absence of a guide plate as shown in Fig. 3, i.e. as in the case of Fig. 1b–2, the rotation of the impeller 2 causes the molten iron 3 to be delivered to the outside with a certain spread from the upper and lower delivering ends of the impeller. Considering only the streams of the molten iron delivered from the upper discharging ends of the impeller 1 (Fig. 3), there are two streams, one flowing substantially horizontally as shown by the solid lines and the other flowing upwardly as shown by the dotted lines. Thus, the motion of the molten iron on the surface of the bath is equivalent to the resultant of the two streams. In the illustrated case, the streams shown by the dotted lines are more intense so that the floating objects on the bath surface tend to gather on the wall side of the vessel.

If, under the same condition, the guide plate 5 is inserted in the molten iron bath diagonally above the impeller 1 as shown in Fig. 4, the molten iron delivered from the upper delivering ends of the impeller 1 is forcibly made to flow downward. The result is that the streams of the molten iron flowing in the directions shown by the dotted lines in Fig. 3 disappear completely by joining with the streams shown by the solid lines 1b–1 and producing intense streams flowing in the directions shown by the solid lines in Fig. 4. Thus, the liquid in the surface portion tends to flow from the wall side of the vessel toward the center of the impeller in strong streams. Consequently, the floating objects are gathered toward the vortex at the center of the impeller and are drawn into the liquid on the strength of the strong streams.

In Figs. 3 and 4, the hatched portions at the ends of the impeller indicate where the liquid is delivered effectively. When the guide plate is inserted, the area of these effective portions is expanded by the downward streams thereby caused, in contrast to the case where no guide plate is employed. Consequently, the intensity of the liquid flowing from the wall side of the vessel toward the impeller is strengthened.

The treating vessel according to the present invention includes both a ladle in which a certain quantity of molten pig iron contained therein is treated by the batch system and a continuous desulphurization vessel which continuously receives molten pig iron being supplied at a substantially constant flow rate and continuously discharges same at a constant flow rate. Fig. 5 illustrates the former case and Fig. 6 illustrates the latter case wherein a plurality of treating vessels are employed for continuous desulphurization.

Fig. 5 concretely illustrates an apparatus designed to carry out the process of the invention as shown in Fig. 2. In this apparatus, the ladle 4 filled with molten pig iron 3 is placed on a ladle car 6 and a stirrer is mounted on a supporting stand 8 comprising four posts provided on a frame 7. The impeller 1 and an impeller shaft 9 are coupled to a rotating shaft 11 by a flange 10. The rotating shaft 11 is supported by a journal box 12 and is connected at its farther end with a driving unit 13 consisting of a motor and a reduction gear. The driving unit 13 is suspended by a wire 15 let out from a winder 14 disposed on the top of the supporting stand 8 and the stirrer including the impeller 1 is vertically moved by the winder 14 through rollers 16 along the supporting stand 8. The guide plate 5 and its attaching shaft 17 are connected to a movable shaft 19 via a coupling 18. Said movable shaft 19 is provided with a lever 20 so that the guide plate can be turned as desired. Disposed below the journal box 12 is a heat insulating plate 21 and the assembly comprising the impeller 1, the guide plate 5 and the heat insulating plate 21 is moved up and down by the vertical motion of the wire 15. A ladle cover 22 is placed on the ladle 4 so that a certain degree of airtightness is maintained during the vertical motion of the centrally disposed heat insulating plate 21. A desulphurizing charging chute 23 and a gas exhaust pipe 24 are provided in the ladle cover 22 and the ladle cover 22 is suspended and moved vertically by means of wires 25 extending from a winder 26 on the frame 7. The desulphurizing agent 2 is stored in a hopper 28 provided with a measuring feeding unit 27 and the desulphurizing agent is fed onto the surface of the molten pig iron bath from the chute 23 through a flexible tube 29.

Fig. 6 illustrates an application of the present invention to an iron runner of a blast furnace designed as a continuous molten pig iron desulphurizing apparatus in which numeral 30 denotes a dammer slab. Slag 31 is led to a slag runner from an outlet 32 and the molten pig iron 3 flows through a dam 33. Dams 35 and 36 are provided in a runner 34 and a stirrer 37 comprising a plurality of sets of impellers 1 and guide plates 5 is provided in each of the flowing passages. The desulphurizing agent is charged onto the surface of the molten iron bath from a hopper 38 by a feeder 39 through a chute 40. A skimmer 41 is provided in the rear of the dam 36 and post-reaction residues 42 of the desulphurizing agent are continuously scrapped out by a scraper 43.

Although only one guide plate is employed for each impeller in the above-described apparatus of the present invention, the number of said guide plate is not necessarily limited to one but a plurality of guide plates may be employed simultaneously.

Examples of processes according to the present invention will now be given hereunder.

**EXAMPLE 1**

An impeller 60 cm in diameter and 40 cm in height having five blades was immersed in a 30 t ladle having a diameter of 1.8 m and containing molten pig iron of 2.0 m depth in such a manner that the distance between the molten iron bath surface and the upper surface of the impeller was 35 cm and the impeller was rotated at a speed of 75 rpm. A guide plate having a width of 50
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5 cm was immersed to a depth of 18 cm from the bath surface. As a desulphurizing agent, 3 kg/t of calcium carbide was used. The desulphurization rate obtained after 12 minutes of agitation in the presence of a guide plate was 85–95% in contrast to the desulphurization rate of 35–45% obtained in the absence of a guide plate. In this case, the temperature of the molten pig iron was 1350°C ±20°C and the sulphur content of the molten iron was between 0.03 and 0.06%. Sufficient removal of the slag was effected in this example.

When a guide plate was not used, the desulphurizing agent was found circulating together with the upper layer of the molten iron bath.

EXAMPLE 2

An impeller 60 cm in diameter and 40 cm in height having five blades was immersed in a 30 t ladle having a diameter of 1.8 m and containing molten pig iron of 2.0 m depth in such a manner that the distance between the bath surface and the upper surface of the impeller was 35 cm and the impeller was rotated at a speed of 75 rpm. A guide plate of 50 cm in width was immersed to a depth of 5 cm from the bath surface. As a desulphurizing agent, 3 kg/t of calcium carbide was used. The desulphurization rate obtained after 12 minutes of agitation in the absence of a guide plate was 25–35%.

The desulphurizing agent was found congesting on the inner periphery of the ladle. On the contrary, when a guide plate was employed, the desulphurizing agent was satisfactorily drawn into the molten iron and the desulphurization rate obtained was 85–95%. In this example, the temperature of the molten pig iron was 1350°C ±20°C and the sulphur content of the molten iron was between 0.03 and 0.06%.

EXAMPLE 3

This is an example of a 2 t/min continuous treatment apparatus. The vessel used was 1.65 m in length and 0.75 m in width, and the depth of the molten iron bath was 0.60 m. The amount of molten pig iron contained in the vessel was about 4 tons, that is to say, the average retention time of molten iron was 2 minutes. Two impellers each having a diameter of 25 cm and a thickness of 15 cm, and provided with three blades were immersed in the bath to a depth of 20 cm from the bath surface and rotated at a speed of 80 rpm. A guide plate of 20 cm in width was immersed in the bath to a depth of 14 cm from the bath surface in a manner to be located diagonally above each impeller. Calcium carbide was fed to the molten iron per 6 kg/min. The desulphurization rate obtained was about 40% in the absence of a guide plate and about 70% in the presence of guide plates. In this example, the temperature of the molten pig iron was 1400°–1450°C and the sulphur content of the molten iron before desulphurization was between 0.03 and 0.06%.

FIG. 7 graphically shows a comparison of desulphurization rates in the presence and absence of a guide plate obtained from other examples.

It is evident from these comparative tests that the processes according to the present invention show excellent desulphurization rates at a low speed of rotation of the impeller.

The following table shows how the process of this invention is advantageous over the conventional process wherein agitation is conducted by an impeller alone.

<table>
<thead>
<tr>
<th>Space factor of ladle</th>
<th>100</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power cost for impeller</td>
<td>30 – 50</td>
<td>100</td>
</tr>
<tr>
<td>Equipment cost for desulfurization</td>
<td>50 – 60</td>
<td>100</td>
</tr>
<tr>
<td>Life of impeller</td>
<td>300</td>
<td>100</td>
</tr>
</tbody>
</table>

Notes: The figures in the table are typical and estimated figures designed solely for comparison between the two cases.

As stated above, the present invention provides an excellent method for desulphurizing molten pig iron in a short time through the steps of causing molten pig iron in a ladle to move horizontally in one direction by a rotating impeller, and creating downward streams in the molten pig iron bath by inserting a guide plate in the upper part of the bath, thereby causing the desulphurizing agent to be drawn into said downward streams and making it possible for the desulphurizing agent to get under the bath surface even when the impeller is rotated at a slow speed. The fact that satisfactory results are obtained from low-speed rotation of the impeller means an economic advantage that a small-scale equipment for rotation suffices. There is also an advantage that an increased amount of molten pig iron can be treated at a time with respect to the capacity of the vessel since, even when the impeller is rotated at a relatively high speed, not to speak of the case of low speed rotation, little swelling of the bath is seen on the surface thereof, the speed of rotation of the impeller not being the only factor for drawing the desulphurizing agent into the molten pig iron. Furthermore, low-speed rotation of the impeller serves to decrease the wear of the impeller and the inner wall of the ladle. Taken altogether, the desulphurization process of the present invention can safely be called a very economical one.

What is claimed is:

1. A method of desulphurizing molten pig iron in a vessel, comprising the steps of mechanically stirring said molten pig iron with a rotating impeller disposed in said molten pig iron, the rotating impeller having a shaft which is substantially vertically disposed in the vessel, thereby creating a circulating upper layer of molten pig iron and a substantially static lower layer of molten pig iron, the upper layer having streams flowing substantially horizontally therein; immersing a guide plate into said molten pig iron to a depth of between one-fourth and three-fourths of the distance between the surface of said molten pig iron when the molten pig iron is static in said vessel and the upper surface of said impeller, thereby creating other streams of molten pig iron flowing substantially downwardly therein; and charging a desulphurizing agent into said molten pig iron from the uppermost surface thereof, said desulphurizing agent being drawn into said substantially downwardly flowing streams and under the upper surface of said molten pig iron and under the circulating streams of said upper layer.

2. The method according to claim 1 comprising immersing a guide plate having a width of between one-fourth and two-thirds of the radius of said vessel into said molten pig iron.
3. The method according to claim 1 comprising mechanically stirring said molten pig iron with a plurality of said rotating impellers, and immersing a plurality of guide plates into said molten pig iron, in at least one of said vessels.

4. The method according to claim 1 comprising rotating said impeller at a speed approximately 50–80% of the speed required to form a vortex pattern in said molten pig iron without a guide plate.

5. The method according to claim 1, wherein said vessel is a ladle.

6. The method according to claim 1, wherein a plurality of vessels are arranged in series for continuous desulfurization of molten pig iron.

7. The method according to claim 1, wherein said guide plate is positioned in said vessel such that a portion of said guide plate is located directly above the locus described by said impeller.

* * * * *