Supersonic injection of oxygen in cupolas.
Description

The present invention relates to a process for producing molten metal in a cupola furnace.

The conventional cupola furnace is essentially a shaft furnace. At the bottom of the shaft is a well portion for collecting the molten metal and for initially receiving a bed charge coke. Closely spaced above the well are tuyeres for feeding large volumes of air under pressure. In the upper portions of the shaft there is provided a charge port. A cupola furnace is employed in metal melting as opposed to metal refining processes.

Normal cupola operation is essentially simple. The vertical shaft furnace is packed with coke, which is caused to burn by air forced in the bottom through the tuyeres, producing heat. Metal, placed on top of the glowing coke bed, melts and drips through the coke, collecting in the well or hearth, where it is removed periodically through a tapping hole.

When the incoming air, referred to in the art as the air blast, comes in contact with the burning coke, the latter is burned to carbon dioxide. This immediately reacts with further coke to form carbon monoxide, but in so doing absorbs about 45% of the heat emitted by the original carbon dioxide combustion reaction. As the carbon monoxide ascends through the column of coke and becomes cooler, some of it decomposes to carbon dioxide and carbon, an exothermic reaction.

The gases discharged from the shaft are thus a mixture of carbon monoxide, carbon dioxide and nitrogen. These hot discharged gases carry out about 10 percent of the heat produced by combustion of the coke. About 45 percent of the heat produced is removed by the molten metal, and the remaining 45 percent of the heat produced is used up by the afore-mentioned incomplete combustion reaction.

Those skilled in the art have devised several methods to alleviate the inefficiencies caused by this incomplete combustion. One such method has been to enrich the incoming air with oxygen. This method has given good results, but is characterized by oxygen losses through leaks and some loss in the control of the chemistry of the molten metal.

Another method which has found wide use in the industry is the injection of extra oxygen directly into the burning coke. When oxygen is introduced in this manner, combustion is much more rapid near the hearth and the length of the zone of combustion tends to be less than with air alone. This causes the top of the coke bed to be somewhat cooler and this in turn causes a correspondingly greater decomposition of carbon monoxide to carbon dioxide and carbon, accompanied by a greater release of heat. This produces a hotter metal, a reduction in the amount of coke required per ton of metal and a higher carbon content in the metal. One such method is disclosed in US—A—3 089 766 in which oxygen is injected directly into one or more tuyeres at velocities greater than that of the air blast. Another method is disclosed in GB—A—914 504 in which oxygen is injected into the furnace through tuyeres located below the tuyeres through which air is introduced. Still another method is disclosed in GB—A—1 006 274 in which oxygen is injected into the furnace through tuyeres located at the same level as the tuyeres through which air is introduced but in such a manner that the jets of air and oxygen impinge on different areas of the coke charge without substantial intermixing.

Furthermore it is known from GB—A—2 018 295 to introduce into a cupola furnace a blast of air through the air tuyeres of the furnace, and to provide in at least one of the main tuyeres a Laval nozzle the inlet of which receives oxygen and from the outlet of which a jet of oxygen at supersonic velocity passes into the combustion region of the furnace remote from the refractory lining of the furnace, wherein typically oxygen may be supplied from the or each Laval nozzle at a rate of up to 4% by volume of the rate at which air is introduced into the furnace from its associated tuyers.

Because of the significant economic importance of the metal melting operation in cupola furnaces a method which would improve the efficiency of the process over that heretofore obtained would be highly desirable. Accordingly it is an object of this invention to provide a more efficient method of melting metal in a cupola furnace.

In conformity with the present invention a process for producing molten metal in a cupola furnace comprising:

a) charging coke and metal to the cupola furnace,

b) causing said coke to burn by the introduction of first oxygen-containing gas,

c) additionally injecting at supersonic velocity directly into said cupola furnace a second oxygen-containing gas, having an oxygen concentration greater than said first oxygen-containing gas, said second oxygen-containing gas being injected at a flow rate equivalent to that required to enrich the oxygen concentration of said first oxygen-containing gas by from 0.5 to 10 percent,

is characterized in that said second oxygen-containing gas is directly injected into said cupola furnace at a velocity of from 442 to 503 m/s through different tuyeres on the same level or on different levels separately from the first oxygen-containing gas.

The basic design and operation of a cupola are well known by those skilled in the art. Illustrative patents which describe cupolas and their operation include, for example, US—A—3 089 766 and US—A—4 045 212.

In practicing the process of the present invention, the charging and firing of the cupola is carried out in a conventional manner. For example, the coke in the bottom of the cupola above the hearth is ignited, and the depth of the coke bed regulated by the amount of coke.
charged into the shaft furnace at the top. An oxygen-containing gas, such as air, is supplied to the cupola through the tuyeres. The cupola charge normally comprises a layer of coke and subsequent layers of metal and coke until the desired amount of material has been introduced. Additional quantities of metal and coke may be added as rapidly as the charge lowers within the shaft. Limestone or other fluxing material may be added to the top of each coke charge in order to reduce the viscosity of the cupola slag. During the operation of the cupola furnace, drops of molten metal flow down through the coke bed and collect between the lumps of coke in the well or crucible portion at the bottom of the cupola furnace. Likewise, the lighter molten slag accumulate within the coke bed below the tuyeres until it approaches the top of the crucible where it is discharged from the cupula through a slag spout. The molten metal from the cupula and allowed to run out through a tapping spout located at the base of the crucible below the slag spout.

As mentioned previously oxygen has been added to the oxygen-containing gas to enrich it. The oxygen-containing gas is usually air which has an oxygen content of about 21 percent. Oxygen or an oxygen-rich gas is added to the air at a flow rate such that the gas supplied to the cupola has the desired oxygen content. For example, if the oxygen content on the total gas supplied to the cupola is 23 percent, this is 2 percent enrichment.

A second oxygen-containing gas is supplied separately from the first oxygen-containing gas through different tuyeres directly to the cupola furnace at a flow rate such that if it were provided to the first oxygen-containing gas it would result in from 0.5 to 10 percent enrichment. The second oxygen-containing gas must have an oxygen concentration greater than that of the first oxygen-containing gas.

The first oxygen-containing gas is generally, and preferably, air which has an oxygen concentration of about 21 percent. The second oxygen-containing gas has an oxygen concentration greater than the first oxygen-containing gas, generally from 50 to 100 percent oxygen, preferably from 90 to 100 percent oxygen, most preferably from 99 to 100 percent oxygen.

In the process of this invention the second oxygen-containing gas is directly injected into the cupola furnace at a velocity of from 442 to 503 m/s, i.e. a velocity considerably higher than the velocity of sound. The injection of this gas separately from the first oxygen-containing gas at such a velocity results in several improvements in the operation of the cupola furnace, such as greater combustion reaction penetration which results in decreased coke or fuel requirements to sustain the melting characteristics of the cupola furnace, increased silicon recovery, higher carbon pickup, and cooler cupola walls.

The second oxygen-containing gas is injected directly to the cupola furnace separately from the first oxygen-containing gas through different tuyeres. The latter may be on the same level or on different levels as each other and may be on the same side of the cupola proximate to one another or on different sides as much as 180° apart from one another.

The second oxygen-containing gas impinges on the burning coke at supersonic velocity. If the first and second oxygen-containing gas are injected into the cupula furnace from positions proximate to one another, intermixing of the two gas streams may begin to occur before impingement on the burning coke. However, there need not be any intermixing of the two gas streams before such impingement.

As previously mentioned, the second oxygen-containing gas is injected at a velocity from 1450 to 1650 feet per second (442 to 503 m/s per second). The speed of sound through dry air at 0°C is 1087 feet per second (331.4 meters per second); under similar conditions the speed of sound through oxygen is 315 meters per second.

The second oxygen-containing gas is injected at a flow rate equivalent to that required to enrich the oxygen concentration of the first oxygen-containing gas by from 0.5 to 10 percent, preferably from 0.5 to 5 percent, most preferably from 1 to 4 percent.

The metal is charged to the cupola furnace as a solid. The metal may be any metal suitable for melting in a cupola furnace. Often the metal is a ferrous metal such as gray iron, scrap iron, pig iron or steel scrap.

**Claims**

1. A process for producing molten metal in a cupola furnace comprising:
   (a) charging coke and metal to the cupola furnace,
   (b) causing said coke to burn by the introduction of a first oxygen-containing gas,
   (c) additionally injecting at a supersonic velocity directly into said cupola furnace a second oxygen-containing gas having an oxygen concentration greater than said first oxygen-containing gas, said second oxygen-containing gas being injected at a flow rate equivalent to that required to enrich the oxygen concentration of said first oxygen-containing gas by from 0.5 to 10 percent, characterized in that said second oxygen-containing gas is directly injected into said cupola furnace at a velocity of from 442 to 503 m/s through different tuyeres on the same level or on different levels separately from the first oxygen-containing gas.

2. The process of claim 1 wherein said second oxygen-containing gas has an oxygen concentration of from 50 to 100 percent.

3. The process of claim 1 wherein said second oxygen-containing gas has an oxygen concentration of from 90 to 100 percent.

4. The process of claim 1 wherein said second oxygen-containing gas has an oxygen concentration of from 99 to 100 percent.
5. The process of claim 1 wherein said second oxygen-containing gas is injected at a flow rate equivalent to that required to enrich the oxygen concentration of said first oxygen-containing gas by from 0.5 to 5 percent.

6. The process of claim 1 wherein said second oxygen-containing gas is injected at a flow rate equivalent to that required to enrich the oxygen concentration of said first oxygen-containing gas by from 1 to 4 percent.

7. The process of claim 1 wherein said metal is a ferrous metal.

8. The process of claim 1 wherein said metal is iron.

9. The process of claim 1 wherein said first oxygen-containing gas is air.

**Patentansprüche**

1. Verfahren zum Erzeugen von geschmolzenem Metall in einem Kupolofen, bei dem:
   (a) Koks und Metall in den Kupolofen eingebracht werden,
   (b) der Koks durch Einleiten eines ersten sauerstoffhaltigen Gases zum Brennen gebracht wird,
   (c) in den Kupolofen zusätzlich mit Überschallgeschwindigkeit direkt ein zweites sauerstoffhaltiges Gas eingeleitet wird, das eine größere Sauerstoffkonzentration als das erste sauerstoffhaltige Gas hat und das in einer Durchflussmenge eingeblasen wird, die äquivalent der zur Anreicherung der Sauerstoffkonzentration des ersten sauerstoffhaltigen Gases um 0,5 bis 10 Prozent erforderlichen Durchflussmenge ist,
   dadurch gekennzeichnet, daß das zweite sauerstoffhaltige Gas getrennt von dem ersten sauerstoffhaltigen Gas durch andere Blasformen auf der gleichen Höhe oder auf unterschiedlichen Höhen in den Kupolofen mit einer Geschwindigkeit von 442 bis 503 m/s unmittelbar eingeblasen wird.

2. Verfahren nach Anspruch 1, bei dem das zweite sauerstoffhaltige Gas eine Sauerstoffkonzentration von 50 bis 100 Prozent hat.

3. Verfahren nach Anspruch 1, bei dem das zweite sauerstoffhaltige Gas eine Sauerstoffkonzentration von 90 bis 100 Prozent hat.

4. Verfahren nach Anspruch 1, bei dem das zweite sauerstoffhaltige Gas eine Sauerstoffkonzentration von 90 bis 100 Prozent hat.

5. Verfahren nach Anspruch 1, bei dem das zweite sauerstoffhaltige Gas in einer Durchflussmenge eingeblasen wird, die äquivalent der zur Anreicherung der Sauerstoffkonzentration des ersten sauerstoffhaltigen Gases um 0,5 bis 5 Prozent erforderlichen Durchflussmenge ist.

6. Verfahren nach Anspruch 1, bei dem das zweite sauerstoffhaltige Gas in einer Durchflussmenge eingeblasen wird, die äquivalent der zur Anreicherung der Sauerstoffkonzentration des ersten sauerstoffhaltigen Gases um 0,5 bis 5 Prozent erforderlichen Durchflussmenge ist.

Anreicherung der Sauerstoffkonzentration des ersten sauerstoffhaltigen Gases um 1 bis 4 Prozent erforderlichen Durchflussmenge ist.

7. Verfahren nach Anspruch 1, bei dem das Metall ein Eisenmetall ist.

8. Verfahren nach Anspruch 1, bei dem das Metall Eisen ist.

9. Verfahren nach Anspruch 1, bei dem das erste sauerstoffhaltige Gas Luft ist.

**Revendications**

1. Procédé de production d'un métal fondu dans un cubilof, qui consiste:
   (a) à charger du coke et un métal dans le cubilof,
   (b) à faire brûler le coke par l'introduction d'un premier gaz contenant de l'oxygène,
   (c) à injecter en outre à vitesse supersonique, directement dans le cubilof, un second gaz contenant de l'oxygène dont la concentration en oxygène est supérieure à celle du premier gaz contenant de l'oxygène, ce second gaz contenant de l'oxygène étant injecté à un débit équivalent à celui qui est requis pour enrichir la concentration en oxygène du premier gaz contenant de l'oxygène de 0,5 à 10 %, caractérisé en ce que le second gaz contenant de l'oxygène est injecté directement dans le cubilof à une vitesse de 442 à 503 m/s par des buses différentes au même niveau ou à des niveaux différents, séparément du premier gaz contenant de l'oxygène.

2. Procédé suivant la revendication 1, dans lequel le second gaz contenant de l'oxygène a une concentration en oxygène de 50 à 100 %.

3. Procédé suivant la revendication 1, dans lequel le second gaz contenant de l'oxygène a une concentration en oxygène de 90 à 100 %.

4. Procédé suivant la revendication 1, dans lequel le second gaz contenant de l'oxygène a une concentration en oxygène de 99 à 100 %.

5. Procédé suivant la revendication 1, dans lequel le second gaz contenant de l'oxygène est injecté à un débit équivalent à celui qui est requis pour enrichir de 0,5 à 5 % la concentration en oxygène du premier gaz contenant de l'oxygène.

6. Procédé suivant la revendication 1, dans lequel le second gaz contenant de l'oxygène est injecté à un débit équivalent à celui qui est requis pour enrichir de 1 à 4 % la concentration en oxygène du premier gaz contenant de l'oxygène.

7. Procédé suivant la revendication 1, dans lequel le métal est le fer.

8. Procédé suivant la revendication 1, dans lequel le premier gaz contenant de l'oxygène est de l'air.