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(54) METHOD FOR DETECTING AIR FLOW DISTRIBUTION IN BLAST FURNACE

(57) A method for detecting an air flow distribution in a blast furnace, taking into account a heat exchange between an air flow and a solid material bed and the effect of a distribution of a material layer structure in a radial direction of a blast furnace on the radial air permeability of blast furnace, which affects a mode of air flow distribution, wherein the distribution of the air flow and the radial material layer structure of the blast furnace can be calculated by combining a cross-shaped temperature-measuring gun and other main blast furnace operating parameters. According to the detection method, a blast furnace operator can timely and accurately infer, from a change in a current radial air flow temperature distribution, the direction of change of the distribution of the air flow and the radial material layer structure at a furnace throat portion, thus providing a direction for the adjustment of a material distribution system, ensuring the blast furnace to run stably and smoothly, extending a service life and reducing a fuel ratio without other expensive detecting instruments.

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Description

[0001] This application claims the priority to Chinese patent application No. 201410446536.6, which is titled "METHOD FOR DETECTING AIR FLOW DISTRIBUTION IN BLAST FURNACE" and filed with the Chinese State Intellectual Property Office on September 3, 2014, the entire disclosure of which is incorporated herein by reference.

Field of the invention

[0002] This application belongs to the technical field of numerical simulation of gas flow distribution in blast furnace, and in particular relates to a method for detecting gas flow distribution in blast furnace.

Background of the invention

[0003] A blast furnace is an iron-making vertical furnace with a circular cross section, which generally employs steel plates as a furnace mantle, and the furnace mantle is lined with refractory bricks. A body of blast furnace is divided into five parts from top to bottom: furnace throat, furnace stack, furnace bosh, furnace belly, and furnace hearth. As blast furnace iron-making technology has advantages such as good economic indicators, simple process, large production capacity, a high productivity, low energy consumption and the like, iron produced in this way accounts for a majority of the total iron production of the world.

[0004] During production with the blast furnace, iron ore, coke and flux for slagging (limestone) are charged from the top of the furnace, and preheated air is blown from tuyere located at a lower part of the furnace along the furnace periphery. In a high temperature, carbon in the coke (some blast furnaces are injected therein with pulverized coal, heavy oil, natural gas and other auxiliary fuels) is burnt along with oxygen in the blown air to generate carbon monoxide and hydrogen, which removes oxygen in the iron ore while ascending in the furnace, thereby reducing the iron ore to obtain iron. The molten iron smelted is discharged from a taphole. The impurities not reduced in the iron ore are combined with the flux such as limestone to generate slag which is discharged together with the molten iron from the taphole and is separated by a skimmer. The generated gas is exhausted from the top of the furnace, and is used after being de-dusted as a fuel for hot stove, heating furnace, coke oven, boiler, and the like. The blast furnace smelting produces pig iron as a main product, as well as blast furnace slag and blast furnace gas as by-products.

[0005] Among various factors affecting the blast furnace, the gas flow distribution is critical to the blast furnace operation, therefore, it is often said that "iron-making is just manipulating gas behavior". As is well known, the gas flow distribution is the most important standard for the adjustment of material distribution system of a blast furnace, which reflects whether the current blast furnace operation is stable or not, and determines the utilization rate of blast furnace gas. For such a high-temperature high-pressure airtight container of blast furnace, how to obtain information of the gas flow is very important.

[0006] In the art, generally, the size of the flame burning at the furnace throat is observed by infrared imaging at the furnace top to determine the change of the gas flow, and the temperature of a thermocouple at the furnace throat is observed to determine the change of the gas flow at the edge. However, less information is acquired. Some iron and steel plants further develop gas sampling equipment in a radial direction of the throat to analyze the compositional distribution of gas flow in the radial direction. However, it cannot realize on-line detection and has a safety issue of gas leakage. Currently, most of blast furnaces have a cross-shaped temperature-measuring gun mounted at the furnace top for on-line monitoring the distribution of the gas flow temperature in the radial direction, however, the information acquired is limited, and the distribution of the gas flow cannot be comprehensively reflected solely by the temperature distribution. In the prior art, for example, Russian Patent SU1330163 also discloses a method for detecting a radial gas flow distribution in blast furnace, in which gas composition is measured by a gas sampling device inserted inside the burden, and before and after each batch of burden is distributed, radial gas flow temperature distribution is measured by infrared imaging, and then the radial gas flow distribution is calculated by an empirical formula based on the average furnace top gas flow rate, temperature, time difference, and specific heat of the burden. However, the measurement relies on expensive infrared measurement device, and the gas sampling device in the furnace may interfere with unloading of the burden and accelerate abrasion to the lining of blast furnace. In addition, it is assumed that the burden layer thickness and heat conduction are uniform in the radial direction, whereas in practical production with the blast furnace, the burden layer thickness and heat conduction vary significantly in the radial direction.

[0007] Therefore, a technical problem to be addressed urgently by blast furnace iron-making enterprises has been always to find a more accurate and convenient method for detecting gas flow distribution in blast furnace.

Summary of the invention

[0008] In view of this, the technical problem to be addressed by the present application is to provide a method for detecting radial gas flow distribution in blast furnace which enables a blast furnace operator to obtain the change of the gas flow distribution and the burden layer structure distribution promptly when main operating parameters change, and to timely and accurately adjust the material distribution system, thereby to obtain an ideal gas flow distribution, to reduce a fuel ratio, and maintain a stable and smooth operation of blast furnace at the same time.

[0009] The present application discloses a method for detecting gas flow distribution in blast furnace, characterized in comprising the following steps:

a) dividing a cross-section of blast furnace throat according to the number and positions of temperature-measuring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1;

b) obtaining a solid-gas heat flow ratio of each of the temperature-measuring device regions according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region;

c) establishing a function relation between a thickness ratio of burden material layers and a gas flow rate within each of the temperature-measuring device regions according to the solid-gas heat flow ratio of each of the temperature-measuring device regions;

d) obtaining the thickness ratio of burden material layers within each of the temperature-measuring device regions according to pressure drop per unit length of burden layer, particle size distribution of the burden materials and gas resistance equation of each lump zone of blast furnace, and obtaining the gas flow rate of each of the temperature-measuring device regions according to the thickness ratio of burden material layers within each of the temperature-measuring device region above and the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device region obtained in the above step c); and

e) plotting the region distribution of each of the temperature-measuring device regions and the gas flow rate thereof, to obtain a detection result of the gas distribution.

[0010] Preferably, after step d), the detection method further includes:

d#) obtaining by calculation an average thickness ratio of burden material layers according to the thickness ratio of burden material layers within each of the temperature-measuring device regions, and obtaining a total volume of gas flow passing through the temperature-measuring device regions according to gas flow rate in each of the temperature-measuring device regions, to further obtain a total heat of gas flow passing through the temperature-measuring device regions;

comparing the average thickness ratio of burden material layers obtained in the above step with a theoretical average thickness ratio of burden material layers, to obtain an error $\sigma 1$; comparing the total volume of gas flow passing through the temperature-measuring device regions obtained in the above step with a theoretical total volume of furnace top gas flow, to obtain an error $\sigma 2$; and comparing the total heat of gas flow passing through the temperature-measuring device regions with a theoretical total heat of furnace top gas flow, to obtain an error $\sigma 3$;

modifying the pressure drop per unit length of burden layer and the particle size distribution of burden materials if one or more of the errors $\sigma 1$, $\sigma 2$, and $\sigma 3$ has a value greater than or equal to 5%, and performing the step d) again, until the value of each of the errors $\sigma 1$, $\sigma 2$, and $\sigma 3$ is less than 5%; and

performing the above step e) if the value of each of the errors $\sigma 1$, $\sigma 2$, and $\sigma 3$ is less than 5%.

[0011] Preferably, the burden materials are ore and coke, and the theoretical average thickness ratio of burden material layers is calculated based on a formula: $X_0=[L_O/(L_O+L_C)]_0$, wherein Lo is a thickness of ore layer, and Lc is a thickness of coke layer.

[0012] Preferably, the thickness ratio of burden material layers within each of the temperature-measuring device regions is x_i, the average thickness ratio of burden material layers is X_t, and the average thickness ratio of burden material layers is calculated based on a formula:

$$X_t = \sum_{i=1}^{N} x_i \cdot S_i / A$$

wherein S_i is an area of each of the temperature-measuring device regions, and A is a total area of the cross-section of the blast furnace throat.

[0013] Preferably, the burden materials are ore and coke, the thickness ratio of burden material layers in the temperature-measuring device region is x_i, the gas flow rate in the temperature-measuring device region is u_i, then the function relation between the thickness ratio of burden material layers and the gas flow rate in the temperature-measuring device region is:

$$x_i = (\frac{C_s G_s}{C_g G_g})_i \cdot \frac{(C_g)_i (\rho_g)_i}{C_s (\rho_O - \rho_C) v_i} u_i - \frac{\rho_C}{(\rho_O - \rho_C)}$$

wherein C_g is a specific heat of gas, C_s is a specific heat of solid, G_g is a flow rate of gas, G_s is a flow rate of solid, ρ is a density of furnace top gas , v is a descent velocity of the solid burden bed, ρ_O is a density of ore, and ρ_C is a density of coke.

[0014] Preferably, the gas resistance equation of each lump zone of blast furnace according to the present application is:

$$(\frac{\Delta P}{L})_i = [k_1{}^* \frac{(1-\varepsilon)^2}{D_p{}^2 \varepsilon^3} \cdot \mu u + k_2{}^* \frac{(1-\varepsilon)}{D_p \varepsilon^3} \rho u^2]_i$$

wherein k_1* is a viscous resistance coefficient, k_2* is an inertia resistance coefficient, $\Delta P/_L$ is a pressure drop per unit length, ε is a burden bed porosity, Dp is an average particle diameter of particles, μ is a gas viscosity, u is a gas flow rate, and ρ is a gas density;

the viscous resistance coefficient of the coke and the inertia resistance coefficient of the coke are respectively:

$$k_1^* = 450 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 2.2 \cdot (D_p \cdot 10)^{0.04};$$

the viscous resistance coefficient of the ore and the inertia resistance coefficient of the ore are respectively:

$$k_1^* = 260 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 1.2 \cdot (D_p \cdot 10)^{0.04}.$$

[0015] Preferably, the pressure drop per unit length of burden layer in each lump zone of blast furnace is equal to each other,

the pressure drop per unit length of burden layer in each lump zone of blast furnace is equal to the sum of a pressure drop per unit length of coke and a pressure drop per unit length of ore in said lump zone of blast furnace.

[0016] Preferably, the temperature-measuring device is a cross-shaped temperature-measuring gun.

[0017] The present application further disclose a system for detecting gas flow distribution in blast furnace, characterized in comprising:

a division unit, configured to divide a cross-section of blast furnace throat according to the number and positions of temperature-measuring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1;

a first attainment unit, configured to obtain a solid-gas heat flow ratio of each of the temperature-measuring device regions according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region;

an establishment unit, configured to establish a function relation between a thickness ratio of burden material layers and a gas flow rate within each of the temperature-measuring device regions according to the solid-gas heat flow ratio of each of the temperature-measuring device regions;

a second attainment unit, configured to obtain the thickness ratio of burden material layers within each of the temperature-measuring device regions according to pressure drop per unit length of burden layer, particle size distribution of the burden materials and gas resistance equation of each lump zone of blast furnace, and to obtain the gas flow rate of each of the temperature-measuring device regions according to the thickness ratio of burden material layers within each of the temperature-measuring device region above and the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device region obtained in the above step c); and

a result unit, configured to plot the above distribution of each of the temperature-measuring device regions and the gas flow rate thereof, to obtain a detection result of the gas distribution.

[0018] Preferably, the system further includes:

a verification unit, configured to obtain by calculation an average thickness ratio of burden material layers according to the thickness ratio of burden material layers within each of the temperature-measuring device regions, and to obtain a total volume of gas flow passing through the temperature-measuring device regions according to gas flow rate in each of the temperature-measuring device regions, to further obtain a total heat of gas flow passing through the temperature-measuring device regions;

wherein the average thickness ratio of burden material layers obtained in the above step is compared with a theoretical average thickness ratio of burden material layers, to obtain an error $\sigma1$; the total volume of gas flow passing through the temperature-measuring device regions obtained in the above step is compared with a theoretical total volume of furnace top gas flow, to obtain an error $\sigma2$; and the total heat of gas flow passing through the temperature-measuring device regions is compared with a theoretical total heat of furnace top gas flow, to obtain an error $\sigma3$;

the pressure drop per unit length of burden layer and the particle size distribution of burden materials are modified if one or more of the errors $\sigma1$, $\sigma2$, and $\sigma3$ has a value greater than or equal to 5%, and the step d) is performed again, until the value of each of the errors $\sigma1$, $\sigma2$, and $\sigma3$ is less than 5%; and

the step e) is performed in the case that the value of each of the errors $\sigma1$, $\sigma2$, and $\sigma3$ is less than 5%.

[0019] The present application discloses a method for detecting an gas flow distribution in blast furnace, characterized in comprising the following steps: a) dividing a cross-section of blast furnace throat according to the number and positions of temperature-measuring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1; b) obtaining a solid-gas heat flow ratio of each of the temperature-measuring device regions according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region; c) establishing a function relation between a thickness ratio of burden material layers and a gas flow rate within each of the temperature-measuring device regions according to the solid-gas heat flow ratio of each of the temperature-measuring device regions; d) obtaining the thickness ratio of burden material layers within each of the temperature-measuring device regions according to pressure drop per unit length of burden layer, particle size distribution of the burden materials and gas resistance equation of each lump zone of blast furnace, and obtaining the gas flow rate of each of the temperature-measuring device regions according to the thickness ratio of burden material layers within each of the temperature-measuring device region above and the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device region obtained in the above step c); and e) plotting the region distribution of each of the temperature-measuring device regions and the gas flow rate thereof, to obtain a detection result of the gas distribution. Compared with the prior art, the detection method provided according to the present application takes into account heat exchange between the gas flow and the solid burden bed, and the effect of distribution of burden layer structure in a radial direction of blast furnace on the gas permeability in a radial direction of blast furnace (which in turn affects mode of gas flow distribution), and further combines cross-shaped temperature-measuring gun and other main blast furnace operating parameters, to calculate the distribution of the gas flow and the radial material layer structure of blast furnace. According to the detection method provided in the present application, a blast furnace operator can timely and accurately infer, from change in the temperature distribution of current radial gas flow, the change direction of the distribution of the gas flow and the radial material layer structure at a furnace throat portion, thus providing a direction for the adjustment of burden distribution system, ensuring the blast furnace to run stably and smoothly, extending the service life and reducing the fuel ratio without other expensive detecting instruments. With the detection method provided according to the present application, the heat flow ratio distribution, the ore layer thickness ratio distribution and the gas flow rate distribution at various points in the radial direction of blast furnace throat in various operational time periods are calculated, and the changes of respective parameters before and after each change of the burden distribution matrix are compared. The experimental results show that, the direction of each change of the burden distribution matrix is consistent with the direction of the change of the ore layer thickness ratio distribution calculated according to the present application, and changes in the gas flow distribution and the temperature distribution accordingly are also the same as expected.

Brief description of the figure

[0020]

Figure 1 is a diagram showing the arrangement of cross-shaped temperature-measuring guns and the layout of radial temperature measuring regions;

Figure 2 is a schematic view showing the division of internal regions of a blast furnace and gas-solid heat balance in the blast furnace blank zone according to the present application;

Figure 3 shows the position of the burden materials and the moving directions of the solid and gas, and the positions where the on-line monitoring is performed within the blast furnace according to the present application;

Figure 4 shows area of each of regions divided by the temperature-measuring device regions according to Example 1 of the present application;

Figure 5 is a diagram showing the distribution of a radial descent velocity of blast furnace burden according to Example 1 of the present application;

Figure 6 shows an operation situation of a blast furnace of Hongfa 2500# according to the present application from the end of 2013 to early 2014;

Figure 7 shows change of respective parameters from case 1 to case 2 according to the present application;

Figure 8 shows change of respective parameters from case 2 to case 3 according to the present application;

Figure 9 shows change of respective parameters from case 3 to case 4 according to the present application; and

Figure 10 shows change of respective parameters from case 4 to case 5 according to the present application.

Detailed description of the invention

[0021] For further understanding the present application, the preferred embodiments of the present application are described hereinafter with reference to examples of the present application; however, these descriptions are presented only for further explaining features and advantages of the present application, rather than limiting the claims of the present application.

[0022] The present application discloses a method for detecting gas flow distribution in blast furnace, characterized in comprising the following steps:

a) dividing a cross-section of blast furnace throat according to the number and positions of temperature-measuring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1;

b) obtaining a solid-gas heat flow ratio of each of the temperature-measuring device regions according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region;

c) establishing a function relation between a thickness ratio of burden material layers and a gas flow rate within each of the temperature-measuring device regions according to the solid-gas heat flow ratio of each of the temperature-measuring device regions;

d) obtaining the thickness ratio of burden material layers within each of the temperature-measuring device regions according to pressure drop per unit length of burden layer, particle size distribution of the burden materials and gas resistance equation of each lump zone of blast furnace, and obtaining the gas flow rate of each of the temperature-measuring device regions according to the thickness ratio of burden material layers within each of the temperature-measuring device region above and the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device region obtained in the above step c); and

e) plotting the region distribution of each of the temperature-measuring device regions and the gas flow rate thereof, to obtain a detection result of the gas distribution.

[0023] There are no particular requirements on definitions of the symbols and concepts used in the present application, as long as they are common symbols and concepts well known to those skilled in the art.

[0024] There are no particular requirements on the thermodynamic calculation formulas mentioned in the present application, as long as they are thermodynamic calculation formulas well known to those skilled in the art.

[0025] In the present application, first, the cross-section of blast furnace throat is divided according to the number and positions of temperature-measuring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1.

[0026] There are no particular limitations on the blast furnace with the temperature-measuring device, as long as it is an iron-making blast furnace well known to those skilled in the art, but is preferably a blast furnace with 2500 m^3 from Hongfa in the present application. There are no particular limitations on the temperature-measuring device in the present application, as long as it is a device for measuring the temperature of blast furnaces well known to those skilled in the art, and is preferably a cross-shaped temperature-measuring gun according to the present application. In the present application, there are no particular limitations on the number of the cross-shaped temperature-measuring gun, as long as it is a common number of cross-shaped temperature-measuring gun well known to those skilled in the art, and is preferably 2 to 4 according to the present application. In the present application, there are no particular limitations on the number of temperature-measuring points of the cross-shaped temperature-measuring gun, as long as it is a common number of temperature-measuring points of a cross-shaped temperature-measuring gun well known to those skilled in the art, and is preferably 5 to 8, and more preferably 6 to 7 according to the present application. In the present application, there are no particular limitations on the position of the cross-shaped temperature-measuring gun, as long as it is a position of a cross-shaped temperature-measuring gun mounted in blast furnace well known to those skilled in the art, but the cross-shaped temperature-measuring guns are preferably mounted correspondingly to the four walls of blast furnace throat, and more preferably to the east side and the west side, and more preferably the south side and the north side, and most preferably the east, south, west and north sides according to the present application. In the present application, there are no particular limitations on the overall mounting position of the temperature-measuring device, as long as it is the overall mounting position well known to those skilled in the art, and in particular, is preferred in the present application that one cross-shaped temperature-measuring gun is mounted in each of the four directions, i.e., east, south, west and north, of blast furnace throat, in which one cross-shaped temperature-measuring gun has six temperature-measuring points, and each of the other three cross-shaped temperature-measuring guns has five temperature-measuring points. In the present application, there are no particular limitations on the method for setting the temperature-measuring points, as long as it is a method for setting temperature-measuring points of cross-shaped temperature-measuring guns well known to those skilled in the art. The specific method for setting the temperature-measuring points in the present application is preferably implemented in the following steps: the temperature-measuring gun is mounted to be inclined downwards by 15 degrees, and the temperature-measuring points are arranged equidistantly from the center to the edge in a radial direction of blast furnace throat, the space between every two cross-shaped temperature-measuring guns is preferably ranging from 500 mm to 1000 mm, more preferably 600 mm to 900 mm, and most preferably 800 mm. In the present application, there are no particular limitations on the radial direction, as long as it is a radial direction well known to those skilled in the art. The radial direction described in the present application is a radial direction from the center of blast furnace throat to the furnace wall, and the radial direction may be in parallel with a horizontal plane, and may also be not in parallel with a horizontal plane.

[0027] In the present application, there are no particular limitations on the specific number of the temperature-measuring device regions, i.e., the specific value of the N, which can be set as desired by those skilled in the art according to the size of blast furnace and the practical production situation, and is preferably 4 to 8, more preferably 5 to 7, and most preferably 6 according to the present application. In the present application, there are no particular limitations on the method for dividing the regions, as long as it is a method for dividing the temperature-measuring device regions of the cross-shaped temperature-measuring guns well known to those skilled in the art. The specific division method according to the present application is preferably implemented according to the following steps, first, the center of the cross-section of blast furnace throat is taken as a center of circle, and a distance from the center of blast furnace to the middle of every two temperature-measuring points is taken as a radius to draw circles, the cross-section of the furnace throat is divided into six regions along a radial direction, and the areas of the regions are S_1, S_2, S_3, S_4, S_5, S_6, respectively. In each of the temperature-measuring device regions, the temperature points corresponding to the four temperature-measuring guns in the four directions are averaged, i.e., the temperature value of each of the temperature-measuring device regions, to finally obtain the temperature distribution of furnace top gas in the radial direction of the throat.

[0028] Reference may be made to Figure 1 for the preferred embodiments of the cross-shaped temperature-measuring guns and the division of the temperature-measuring device regions in the radial direction as described above. Figure 1 is a diagram showing the arrangement of the temperature-measuring guns and the layout of the radial temperature-measuring device regions.

[0029] In the present application, after the temperature-measuring device regions are divided by the above method, a solid-gas heat flow ratio of each of the temperature-measuring device regions is obtained according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region.

[0030] In the present application, a heat balance may be reached at the part of the lump zone of blast furnace, that is, the temperatures of the solid and the gas are very close to each other, i.e., no heat transfer is happened between the solid and the gas, and this region is a heat balance region. If ignoring the heat loss caused by the chemical reaction and the heat exchange with the furnace wall, a balance equation between the heat flow rate of gas and the heat flow rate of solid is established. The balance equation between the heat flow rate of gas and the heat flow rate of solid is preferably:

$$C_g G_g (dT / dZ) = C_s G_s (dt / dZ),$$

wherein Cg is a specific heat of gas, in a unit of $KJ/m^3 \cdot °C$; C_s is a specific heat of solid, in a unit of kJ/kg • °C; Gg is a flow rate of gas, in a unit of Nm^3/h; G_s is a flow rate of solid, in a unit of kg/h; dT/dZ is a temperature change per unit of gas height, in a unit of °C/m; and dt/dZ is a temperature change per unit of solid height, in a unit of °C/m.

[0031] In the present application, each of the temperature-measuring points meets the above balance equation between the heat flow rate of gas and the heat flow rate of solid, i.e., the gas-solid heat balance equation. Each of the temperature values of the cross-shaped temperature-measuring guns above are imported into the balance equation, the solid-gas heat flow ratios C_sG_s/C_gG_g at various points in the radial direction of the cross-shaped temperature-measuring guns can be calculated, that is, the solid-gas heat flow ratios of corresponding temperature-measuring device regions above the lump zone of blast furnace. The equation of the solid-gas heat flow ratio is C_sG_s/C_gG_g, $i = 1... N$. The corresponding temperature-measuring device regions mean that the temperature-measuring device regions have one-to-one correspondence to the lump zone of blast furnace in the height direction of blast furnace, and are located above the corresponding lump zone of blast furnace. Any one of the temperature-measuring device regions is the i^{th} region, and $1 \le i \le N$; and the i is a natural number greater than or equal to 1.

[0032] In the present application, there are no particular limitations on the lump zone of blast furnace; as long as they are lump zones of blast furnace well known to those skilled in the art. In the present application, there are no particular limitations on the subsequent division of the internal regions of blast furnace, which may be performed by a division method well known to those skilled in the art. The blast furnace is preferably divided according to the present application into five parts, i.e., lump zone, cohesive zone, dripping zone, raceway zone, as well as slag-iron zone, reference may be particularly made to Figure 2 for the temperature distribution of the solid and gas inside the blast furnace, and Figure 2 is a schematic view showing the division of the internal regions of blast furnace and the gas-solid heat balance in the lump zones of blast furnace according to the present application.

[0033] In the present application, the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device regions is established according to the solid-gas heat flow ratio of each of the temperature-measuring device regions obtained in the above step. The burden materials are preferably ore and coke. The thickness ratio of burden material layers in the temperature-measuring device region is preferably x_i, and the gas flow rate in the temperature-measuring device region is preferably u_i. The function relation between the thickness ratio of burden material layers and the gas flow rate in the temperature-measuring device region is preferably:

$$x_i = (\frac{C_s G_s}{C_g G_g})_i \cdot \frac{(C_g)_i(\rho_g)_i}{C_s(\rho_O - \rho_C)v_i} u_i - \frac{\rho_C}{(\rho_O - \rho_C)}$$

where Cg is a specific heat of gas, C_s is a specific heat of solid, Gg is a flow rate of gas, G_s is a flow rate of solid, ρ is a density of furnace top gas, in a unit of kg/m^3, v is a descent velocity of the solid burden bed, in a unit of m/s, ρ_O is a density of ore, in a unit of kg/m^3, and ρ_C is a density of coke, in a unit of kg/m^3.

[0034] In the present application, the equation of the heat flow rate of solid within each of the temperature-measuring device regions is as follows:

$$(C_s G_s)_i = \{C_s vA[\rho_O x + \rho_C(1-x)]\}_i, \quad x = \frac{L_O}{L_O + L_C};$$

the equation of the heat flow rate of gas is $(C_g G_g)_i = (C_g \rho u S)_i$;
wherein S is an area of the cross-section, through which the solid burden bed and the gas flow pass, within the temperature-measuring device region, and S_i is the area of each of the temperature-measuring device regions,

and in $x = \frac{L_O}{L_O + L_C}$, Lo is an ore layer thickness, in a unit of meter, and Lc is a coke layer thickness, in a unit of meter.

[0035] In the present application, there are no particular limitations on the position of the burden material; the flowing direction of the three phases of solid, liquid and gas phases; and the process route within the blast furnace, which may be the operation situation of blast furnace well known to those skilled in the art. Reference may be specifically made to Figure 3, which shows the position of burden material, the moving directions of the solid and gas, and the position where the on-line monitoring is performed within the blast furnace according to the present application.

[0036] In the present application, the thickness ratio of burden material layers within each of the temperature-measuring device regions is then acquired according to the pressure drop per unit length of burden layer (ΔP/L), the particle size distribution of materials and gas resistance equation of each lump zone of blast furnace, and then the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device regions obtained in the above step is combined, to obtain the gas flow rate of each of the temperature-measuring device regions.

[0037] In the present application, for the convenience of subsequent calculation, the pressure drop per unit length of burden layer (ΔP/L) of the lump zone of blast furnace is preferably a preset value, and in the present application, there are no particular limitations on the presetting method of the ΔP/L, which may be a method well known to those skilled in the art, and is preferably set based on the total pressure drop of practical operation of blast furnace and the distance from the tuyere to the burden line according to the present application. The particle size distribution of materials (dp) of the lump zone of blast furnace, i.e., the particle size distribution of the coke and ore in the radial direction of blast furnace are preferably preset values, and in the present application, there are no particular limitations on the setting method of the particle size distribution of materials, which can be a method well known to those skilled in the art. In the present application, the particle size distribution of materials is preferably obtained by correlating with the throat radius, specifically, dp=f(r) ($0 \le r \le 1$), (r is a dimensionless throat radius), and its initial value is set as being uniformly distributed in the radial direction, i.e., dp=D_p. In the present application, there are no particular limitations on the specific correlation method of the particle size distribution of materials in the blast furnace, which can be a measurement method for particle size distribution or distribution curve well known to those skilled in the art. In the present application, there are no particular limitations on the calculation method for the average particle diameter of the particles (D_p), which can be a calculation method for the average particle diameter well known to those skilled in the art, and is preferably an arithmetical average method according to the present application.

[0038] The pressure drop per unit length of burden layer in each lump zone of blast furnace is preferably an value equal to each other, i.e.,

$$(\frac{\Delta P}{L})_1 = (\frac{\Delta P}{L})_2 \cdots (\frac{\Delta P}{L})_N;$$

and the pressure drop per unit length of burden layer in each lump zone of blast furnace is preferably equal to the sum of a pressure drop per unit length of coke and a pressure drop per unit length of ore in said lump zone of blast furnace, that is,

$$(\frac{\Delta P}{L})_i = (\frac{\Delta P}{L})_{O,i} \cdot x_i + (\frac{\Delta P}{L})_{C,i} \cdot (1 - x_i).$$

[0039] The gas resistance equation of each lump zone of blast furnace according to the present application is preferably:

$$(\frac{\Delta P}{L})_i = [k_1{}^* \frac{(1-\varepsilon)^2}{D_p{}^2 \varepsilon^3} \cdot \mu u + k_2{}^* \frac{(1-\varepsilon)}{D_p \varepsilon^3} \rho u^2]_i ,$$

wherein k_1* is a viscous resistance coefficient, k_2* is an inertia resistance coefficient, ΔP/L is a pressure drop per unit length, in a unit of kPa/m, ε is a burden bed porosity, D_p is an average particle diameter of particles, in a unit of meter, μ is a gas viscosity, in a unit of Pa·s, u is a gas flow rate, in a unit of m/s, and ρ is a gas density, in a unit of kg/m^3.

[0040] In the present application, there are no particular limitations on the viscous resistance coefficient and the inertia resistance coefficient, which may be calculated by methods well known to those skilled in the art, and are preferably obtained in the present application according to the calculation method in "Distribution of Burden Materials and Gas permeability in a Large Volume Blast Furnace" published by Yamada (in kawasaki steel giho in 1974, 16-36),
the viscous resistance coefficient and the inertia resistance coefficient of the coke are respectively:

$$k_1^* = 450 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 2.2 \cdot (D_p \cdot 10)^{0.04};$$

and
the viscous resistance coefficient and the inertia resistance coefficient of the ore are respectively:

$$k_1^* = 260 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 1.2 \cdot (D_p \cdot 10)^{0.04}.$$

[0041] According to the present application, in combination with the above equations, under the given ΔP/L and the particle size distribution dp=f(r) ($0 \le r \le 1$) of coke and ore, the thickness ratio of burden material layers x_1, x_2,...x_N and the gas flow rate distribution u_1, u_2,...u_N of each of the temperature-measuring device regions are finally obtained through calculation of above steps.

[0042] For purpose of ensuring the reliability of the calculated data and improving the accuracy of the calculated data, it is preferably according to the present application to verify the above calculated data. In the present application, there are no particular limitations on the method for the verification, which can be a method for verifying the above blast furnace data well known to those skilled in the art, and the verification according to the present application is preferably performed according to the following steps.

[0043] First, an average thickness ratio of burden material layers is calculated according to the thickness ratio of burden material layers within each of the temperature-measuring device regions, a total volume of gas flow passing through the temperature-measuring device regions is obtained according to gas flow rate in each of the temperature-measuring device regions, and a total heat of gas flow passing through the temperature-measuring device regions is further obtained.

[0044] Then, the average thickness ratio of burden material layers obtained in the above step is compared with a theoretical average thickness ratio of burden material layers, to obtain an error σ1; the total volume of gas flow passing through the temperature-measuring device regions obtained in the above step is compared with a theoretical total volume of furnace top gas flow, to obtain an error σ2; and the total heat of gas flow passing through the temperature-measuring device regions is compared with a theoretical total heat of furnace top gas flow, to obtain an error σ3.

[0045] Thereafter, an error analysis is made. The pressure drop per unit length of burden layer and the particle size distribution of burden materials are modified if one or more of the errors σ1, σ2, and σ3 has a value greater than or equal to 5%, and the step d) is performed again, until the value of each of the errors σ1, σ2, and σ3 is less than 5%; and the step e) is performed in the case that the value of each of the errors σ1, σ2, and σ3 is less than 5%.

[0046] In the present application, there are no particular limitations on the kinds of the detection date, which may be the kinds of detection date under normal states of blast furnace well known to those skilled in the art, and are preferably batch data of coke, batch data of ore, gas consumption, as well as composition, temperature, and pressure, or the like of various gases detected at the furnace top. In the present application, there are no particular limitations on the source of the detection date, which can be the source of detection date under normal states of blast furnace well known to those skilled in the art.

[0047] In the present application, the thickness ratio of burden material layers within each of the temperature-measuring device regions calculated by the above steps is firstly calculated to obtain the average thickness ratio of burden material layers; and then the total volume of gas flow passing through the temperature-measuring device regions is obtained according to the above gas flow rate of various temperature-measuring device regions, and the total heat of gas flow passing through the temperature-measuring device regions is in turn obtained. The above average thickness ratio of burden material layers, the total gas flow volume, and the total gas flow heat are all data obtained by calculation according to practical detection data and further through the above calculation method according to the present application.

[0048] The thickness ratio of burden material layers within each of the temperature-measuring device regions is preferably x_i, the average thickness ratio of burden material layers is preferably X_t, and the average thickness ratio of burden material layers is preferably calculated by the following formula:

$$X_t = \sum_{i=1}^{N} x_i \cdot S_i / A ,$$

wherein S_i is an area of each of the temperature-measuring device regions, and A is a total area of the cross-section of blast furnace throat.

[0049] Regarding the total gas flow volume and total gas flow heat, preferably, the distributions of the gas volume V_i and gas heat Q_i at the furnace top are calculated according to the distribution of the gas flow rate u_i, and then the volumes at various points are added together to obtain the total gas flow volume and total heat of gas flow,

$$V_t = V_1 + V_2 + \cdots V_N ,\quad Q_t = Q_1 + Q_2 + \cdots Q_N .$$

[0050] In the present application, the theoretical average ore-coke layer thickness ratio (i.e., the theoretical average thickness ratio of burden material layers) is further calculated according to the given batch data of coke and the given batch data of ore. Then, the volume V_D of dry gas at the furnace top is calculated according to the N_2 in the blast furnace gas by conservation law. According to the kinetics balance of reaction $CO_2+H_2=H_2O+CO$ at the furnace top, the volume V_{H2O} of the water vapor at the furnace top is calculated, to thereby calculating the theoretical total furnace top gas flow volume V_0 and the total furnace top gas heat Q_0, i.e., the theoretical total gas flow volume at the furnace top and the theoretical total gas flow heat at the furnace top. The burden materials are preferably ore and coke, and the calculation formula of the theoretical average thickness ratio of burden material layers is preferably $X_0=[L_O/(L_O+L_C)]_0$, wherein Lo is a thickness of ore layer, and Lc is a thickness of coke layer. In the present application, there are no particular limitations on the calculation method of theoretical total gas flow volume at the furnace top and theoretical total gas flow heat at the furnace top, which can be calculation methods according to the kinetics balance equation of above reaction well known to those skilled in the art.

[0051] In the present application, the X_t, V_t and Q_t calculated by the above calculation methods are compared with the theoretical values X_0, V_0 and Q_0 obtained according to the above equations, to obtain errors σ1, σ2 and σ3. In the present application, there are no particular limitations on the calculation methods of the above errors, which can be calculation methods for errors well known to those skilled in the art. In the present application, there are no particular limitations on the verification scheme of the errors, which can be verification schemes or verification standards well known to those skilled in the art, and are preferably performed according to the following steps in the present application. In the case that any one of the above error values σ1, σ2 and σ3 is greater than or equal to an error limit, the pressure drop per unit length of burden layer (ΔP/L) and the particle size distribution of burden materials (dp=f(r) ($0 \le r \le 1$)) are modified again, and the step for calculating the gas flow rate of various temperature-measuring device regions is performed again, until each of the numerical values of the error values σ1, σ2 and σ3 is less than the error limit; and in the case that the value of each of the error σ1, σ2 and σ3 is less than the error limit, the verification step is stopped. The error limit is preferably ranging from 3% to 7%, more preferably 4% to 6%, and most preferably 5%.

[0052] After the above verification step, if each of the error values is less than the error limit, the distribution of respective temperature-measuring device regions above and the gas flow rate thereof are plotted to obtain the detection result of the gas distribution.

[0053] The present application discloses a method for detecting a burden layer structure and gas flow distribution in a radial direction of blast furnace. The detection method disclosed in the present application is based on the main operation parameters of blast furnace such as blast condition, batch weight of coke and ore, pressure drop, furnace top gas composition and temperature, in which the throat is divided into several annular temperature-measuring device regions according to the temperature-measuring points of the cross-shaped temperature-measuring guns, and gas-solid heat balance and pressure loss of gas flow in the burden material layer in the several temperature-measuring device regions are calculated, to obtain the burden layer structure of the burden materials and the distribution of the gas flow (including velocity, volume and heat) in the radial direction of the throat, and verification and modification are made using mass balance of solid, mass balance of gas, and heat balance. The operator is allowed to obtain the change trends of the burden layer structure and radial distribution of gas flow by indirect means when the furnace conditions, such as the blast condition and the radial distribution form of the cross-shaped temperature-measuring guns, change, and to timely adjust the material distribution system of blast furnace, to thereby obtain a reasonable gas flow distribution, ensure the stable operation and extend the service life of blast furnace, and achieve the purpose of reducing the fuel ratio.

[0054] A system for detecting gas flow distribution in blast furnace is further provided according to the present application, which includes a division unit, a first attainment unit, an establishment unit, a second attainment unit, and a result unit, and preferably further includes a verification unit. The above units have one-to-one correspondence to the corresponding steps of the method for detecting gas flow distribution of blast furnace according to the present application. Since the detection method according to the present application has the above technical effects, the system for detecting gas flow distribution in blast furnace according to the present application also has the same technical effects.

[0055] With the detection method provided according to the present application, the heat flow ratio distribution, the ore layer thickness ratio distribution and the gas flow rate distribution at various points in the radial direction of blast furnace throat in various operational time periods are calculated, and the changes of respective parameters before and after each change of the burden distribution matrix are compared. The experimental results show that, the direction of each change of the burden distribution matrix is consistent with the direction of the change of the ore layer thickness ratio distribution calculated according to the present application, and changes in the gas flow distribution and the temperature distribution accordingly are also the same as expected.

[0056] For further illustrating the present application, the method for detecting gas flow distribution in blast furnace provided according to the present application is described in detail hereinafter with reference to examples, but the scope of the present application is not limited by the following examples.

Example 1

[0057] Firstly, in blast furnace with 2500 m^3 in Hongfa plant of Shagang group, the number and position of the temperature measurement points of the cross-shaped temperature-measuring gun at the top of blast furnace were set, and the distance between the points was measured. One temperature-measuring gun was mounted in each of the four directions, i.e., east, south, west and north, of blast furnace throat, in which one temperature-measuring gun had six temperature-measuring points, and each of the other three temperature-measuring guns had five temperature-measuring points. A circle was drawn by taking the center of blast furnace as a center of the circle and taking the distances from the center of blast furnace to the middle of every two temperature-measuring points as a radius, and the cross-section of the throat was divided into six parts with areas thereof being S_1, S_2, S_3, S_4, S_5 and S_6, respectively. The distribution of areas S_1 to S_6 of respective temperature-measuring device regions was given in Figure 4, which shows area of each region divided with the temperature-measuring device regions of the cross-shaped temperature-measuring guns according to Example 1 of the present application. The cross-shaped temperature-measuring guns was mounted to be inclined downwards by 15 degrees, and the temperature-measuring points were arranged equidistantly from the center to the edge, the space between every two cross-shaped temperature-measuring guns was 800 mm. The temperature points corresponding to the four temperature-measuring guns in the four directions were averaged, obtaining the diagram of the temperature distribution of the furnace top gas in the radial direction of the furnace throat. The above-mentioned arrangement is also shown in Figures 1 to 3.

[0058] Then, on-line detection was performed in the blast furnace, to obtain the detection numerical value. Reference is made to Table 1, which shows operating parameters of the on-line detection in the blast furnace.

Table 1 Operating parameters of the on-line detection in the blast furnace

coke batch (t/charge)	ore batch (t/charge)	furnace top temperature (°C.)	furnace top pressure (kpa)	blast pressure (kpa)	blast capacity (Nm^3/mi n)		burde n veloc ity (Char ge/h)	enriched oxygen (Nm^3/h)		amoun t of coal (t/h)
11.883	69.41	21.27	207	363.1	4547.3		6.247 4	17964		42.05
gas composition					temperature distribution (°C)					
CO(%)	CO_2(%)	H_2(%)	N_2(%)	η_{CO}(%)	T1	T2	T3	T4	T5	T6
20.34	18.93	2.82	56.4	48.2	527	289	110	81.4	85.7	141.3

[0059] The temperature in the heat balance region was set at 1000°C. The model of the present application covers the heat balance from the top of blast furnace to the heat balance region, and ignores the heat loss caused by the chemical reaction of the lump zone, the heat exchange between the gas and the furnace wall, and the heat exchange between the solid and the furnace wall. According to the heat balance between gas and solid, that is, the heat of the gas is exactly transferred to the solid, it satisfies: $C_gG_g(dT/dZ) = C_sG_s(dt/d_Z)$, and each of radial temperature-measuring device regions meets the heat balance: $\frac{C_sG_{s,i}}{C_gG_{g,i}} = \frac{dT/dZ}{dt/dZ} = \frac{\Delta T}{\Delta t} = \frac{1000-T_{g,i}(top)}{1000-T_s(top)}$, wherein T_s(top)=25 °C, $T_{g,i}$(top) is the temperature value from on-line detection in each of temperature-measuring device regions. Based on the above relation, the solid-gas heat flow ratio C_sG_s/C_gG_g in each of the radial temperature-measuring device regions is calculated. As shown in Table 2, the numerical distributions of respective parameters are calculated according to Example 1 of the present application.

[0060] A function relation between the thickness ratio of burden material layers x_i and the gas flow rate u_i in each of the temperature-measuring device regions is established based on the solid-gas heat flow ratio,

$$x_i = (\frac{C_sG_s}{C_gG_g})_i \cdot \frac{(C_g)_i(\rho_g)_i}{C_s(\rho_O-\rho_C)v_i}u_i - \frac{\rho_C}{(\rho_O-\rho_C)}$$

wherein ρ_O is the ore density, taking 2210 kg/m^3, ρ_C is the coke density, taking 500 kg/m^3, L_O is the ore layer thickness (m), L_C is the coke layer thickness (m), and C_s 1245 J/kg. °C.

[0061] According to "Radial distribution of Burden Descent Velocity near Burden Surface in Blast Furnace", published by ICHIDA in ISIJ international, Vol. 36 (1996), No.5, pp. 493-502, the descent velocity of the burden is not uniform in the radial direction of blast furnace throat, and its radial descent velocity distribution is v=0.2259r+0.8529(0≤r≤1) (r is the dimensionless throat radius). Reference is made to Figure 5, which is a diagram showing the radial descent velocity distribution of the burden in blast furnace in Example 1 of the present application. As in the radial direction, the gas flow temperature varies and the gas flow density may also vary accordingly, the gas flow density can be calculated according to $\rho = \rho_0 \frac{P}{P_0} . \frac{T_0}{T}$, wherein ρ_0, P_0 and T_0 are density, pressure and temperature of gas in a standard state, respectively; P and T are pressure and temperature in a working state, respectively, which are measured by an online instrument. As the gas flow temperature varies in the radial direction, the specific heat of the gas varies accordingly at various points in the radial direction. As have been pointed out in "Blast furnace iron-making production technical manuals", the specific heat of the gas at various temperatures is $Cp=a+bT+cT^{-2}$ ($J\cdot mol^{-1}\cdot K^{-1}$), and the coefficients a, b, and c are as shown in Table 3. Therefore, the average specific heat of respective temperature-measuring device regions is $\overline{C_p} = \frac{\int_{T_i}^{1000} C_p dT}{1000-T_i}$, assuming that the gas has the same composition at various points in the radial direction and the specific heat thereof only changes with the temperature, the specific heat of the gas at various points in the radial direction at the furnace top is

$$\overline{C_p} = \alpha_{CO} \cdot \overline{C_{p,CO}} + \alpha_{CO_2} \cdot \overline{C_{p,CO2}} + \alpha_{H_2} \cdot \overline{C_{p,H2}} + \alpha_{H_2O} \cdot \overline{C_{p,H_2O}} + \alpha_{N_2} \cdot \overline{C_{p,N_2}} \quad ,$$

wherein α is the mass percentage of each gas component. As shown in Table 3, Table 3 is the mass percentage of each gas component in Example 1 of the present application.

[0062] Mass percentage of each gas component in Example 1 of the present application

gas	a	b	c	applicable temperature (K)
CO	28.4	0.0041	-46000	298-2500
CO_2	44.14	0.00904	-854000	298-2500
H_2	27.3	0.0033	50000	298-3000
H_2O	30	0.0107	33000	298-2500
N_2	27.9	0.00427	0	298-2500

[0063] Finally, the distribution of the ore layer thickness ratio x_i and the gas flow rate u_i at various points in the radial direction of the cross-shaped temperature-measuring guns were calculated.

[0064] According to the function relation between the thickness ratio of burden material layers x_i and the gas flow rate u_i,

$$x_i = (\frac{C_s G_s}{C_g G_g})_i \cdot \frac{(C_g)_i (\rho_g)_i}{C_s(\rho_O - \rho_C) v_i} u_i - \frac{\rho_C}{(\rho_O - \rho_C)} \quad ①,$$

in the lump zone of blast furnace, the gas resistance equation is applied:

$$\frac{\Delta P}{L} = k_1^* \frac{(1-\varepsilon)^2}{D_p{}^2 \varepsilon^3} \cdot \mu u + k_2^* \frac{(1-\varepsilon)}{D_p \varepsilon^3} \rho u^2 \quad ②,$$

the pressure loss per unit length at each point is equal to the sum of the pressure losses per unit length of coke and ore:

$$(\frac{\Delta P}{L})_i = (\frac{\Delta P}{L})_{O,i} \cdot x_i + (\frac{\Delta P}{L})_{C,i} \cdot (1 - x_i) \quad ③,$$

and the pressure losses per unit length at each point is equal to each other in the lump zones:

$$(\frac{\Delta P}{L})_1 = (\frac{\Delta P}{L})_2 \cdots (\frac{\Delta P}{L})_6 \quad ④,$$

wherein the porosity of the coke is 0.5, the porosity of the ore is 0.43, Dp is the average particle diameter of the particles (m), the average particle diameter of the coke is 0.045 m, and the average diameter of the ore is 0.0173 m.

[0065] As the temperature of the gas flow varies in the radial direction, the gas viscosity also varies accordingly at various points in the radial direction, μ is the gas viscosity (Pa·s), which is calculated according to the Sutherland formula:

$$\mu = 13.85 \times 10^{-6} \frac{T^{\frac{3}{2}}}{T + 102},$$

wherein T is the current gas temperature.

[0066] k_1^* is the viscous resistance coefficient, and k_2^* is the inertial resistance coefficient. For coke:

$$k_1^* = 450 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 2.2 \cdot (D_p \cdot 10)^{0.04},$$

and for ore:

$$k_1^* = 260 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 1.2 \cdot (D_p \cdot 10)^{0.04}.$$

[0067] It can be obtained by combining equations ①, ②, ③ and ④:

$$a_i u^3 + b_i u^2 + c_i u + d_i = 0 \quad ⑤,$$

wherein a_i, b_i, c_i and d_i are all the expressions in relation to $x_i, \varepsilon, D_{p,i}, k^*_{1,i}, k^*_{2,i}$, it can be derived according to the above description that:

$$a_i = f\{x_i, \varepsilon, D_{p,i}, k_{1,i}^*, k_{2,i}^*, \Delta P / L\};\ b_i = g\{x_i, \varepsilon, D_{p,i}, k_{1,i}^*, k_{2,i}^*, \Delta P / L\};$$

$$c_i = h\{x_i, \varepsilon, D_{p,i}, k_{1,i}^*, k_{2,i}^*, \Delta P / L\};\ d_i = k\{x_i, \varepsilon, D_{p,i}, k_{1,i}^*, k_{2,i}^*, \Delta P / L\}.$$

[0068] According to the actual total pressure drop of blast furnace and the height from the tuyere to stock line of blast furnace, the initial value of $\Delta P/L$ was selected to be 0.77Kpa/m, assuming that the coke and the ore have uniform particle size distribution in the radial direction of the furnace throat, a set of solutions can be given by solving equation ⑤ under given conditions: the ore layer thickness ratio distribution x_1, x_2,...x_6, and gas flow rate distribution u_1, u_2,...u_6. As shown in Table 2, Table 2 shows the numerical distributions of respective parameters calculated in Example 1 of the present application.

Verification step

[0069]

(1) The theoretical average thickness ratio of burden material layers at the furnace top, the theoretical total furnace top gas flow volume V_0 and the theoretical total furnace top gas flow heat Q_0 were calculated.

According to the solid consumption, the gas consumption, the gas composition detected at the furnace top and the furnace top temperature given in Table 1, the batch weight of coke given as 12.2t, and the batch weight of ore given as 71t, the average burden layer structure was calculated to be $X_0=[L_O/(L_O+L_C)]_0=0.569$; the blast condition of the tuyere area was as follows: blast volume of 4547 Nm^3/min, enriched oxygen of 17964 Nm^3/h, and pulverized coal injection of 42.05t/h; the gas composition detected by the furnace top on-line gas analyzer was as follows: CO: 20.34%, CO_2: 18.93%, H_2: 2.82%, N_2: 56.4%; gas pressure P_{top}=207kPa, gas temperature T_{top}=121.27 °C. The volume of N_2 introduced through the tuyere was:

$$V_{N2} = BV \cdot 0.79 + N_2coal / 60 + PCI / 60 \cdot 1000 \cdot N_{PCI} \cdot 22.4 / 28,$$

wherein BV was the cold-blast volume, in a unit of Nm^3/min; N_2coal was the flow rate of carrier gas N_2 of pulverized coal, in a unit of Nm^3/h; PCI was the amount of pulverized coal injection, in a unit of t/h; and N_{PCI} was the content of N in the pulverized coal.

According to the equilibrium of N_2, the total volume of dry gas at the furnace top can be calculated as $V_D = V_{N_2} /(N_2\%)$ =6047.4 Nm^3/min, the reaction of water vapor at the furnace top at 450 °C is $CO + H_2O = CO_2 + H_2$, and a reaction equilibrium constant *is* $K = p_{H_2} \cdot p_{CO_2} / p_{CO} \cdot p_{H_2O} = 4.5$, the water vapor at the furnace top can be calculated as V_{H2O}=63.5 Nm^3/min, the total volume of furnace top gas can be calculated as $V_0=V_D+V_{H2O}$=6110.9 Nm^3/min; and the total heat of furnace top gas can be calculated as $Q_0 = C_p \cdot V_0 \cdot (T_{top} - 25)$ =828714 KJ/min.

(2) The average thickness ratio of burden material layers X_t was calculated according to the thickness ratio of burden material layers of the temperature-measuring device regions calculated by the above method in Table 2; the total volume V_i of the gas flow passing through the temperature-measuring device regions was obtained according to the above gas flow rate of each of the temperature-measuring device regions in Table 2, and the total heat Q_i of the gas flow passing through the temperature-measuring device regions was thus obtained. The values of above V_i and Q_i are shown in Table 2, and Table 2 shows the numerical distributions of respective parameters calculated in Example 1 of the present application.

Regarding the average thickness ratio of burden material *layers* $X_t = \sum_{i=1}^{6} x_i \cdot S_i / A$, A was the total area 54.1 m^2 of the throat cross-section; the volume of gas passing through each point can be obtained according to the calculated gas velocity u_i: $V_i = u_i \cdot S_i$ (i = 1 ··· 6). The total volume of gas flow can be obtained by adding the volumes of the gas at respective points $V_t = V_1 + V_2 + \cdots V_6$. Similarly, by accumulating $Q_i = C_p \cdot V_i \cdot [T_i(top) - 25]$ (i=1···6) at each point, the total gas heat $Q_t = Q_1 + Q_2 + \ldots Q_6$ was obtained.

Table 2 the numerical distribution of respective parameters calculated in Example 1 of the present application

calculated parameters	1	2	3	4	5	6
$(CsGs/CgGg)_i$	0.4855	0.7296	0.9128	0.9422	0.9378	0.8807
x_i	0.1269	0.3664	0.6307	0.6628	0.6142	0.4995
u_i	1.328	1.042	0.8457	0.8228	0.8466	0.9241
V_i	41.73	372.6	887	1399	1897	1492
Q_i	31560	142600	106400	110800	161800	246100

(3) Verification of data

The theoretical burden material layer structure X_0 was calculated by the calculated batch weight of ore and coke. The theoretical total furnace top gas flow volume V_0 and the theoretical total furnace top gas flow heat Q_0 had been calculated by the above equilibrium of N_2. X_t, V_t, and Q_t were compared with X_0, V_0 and Q_0 respectively, and the errors σ_1, σ_2 and σ_3 were set as the error $\sigma_1=[X_t - X_0] / X_0$, $\sigma_2= (V_t-V_0)/V_0$, and $\sigma_3=(Q_t-Q_0)/Q_0$ ($0<\sigma_1,\sigma_2, \sigma_3<5\%$). If the errors σ_1, σ_2 and σ_3 exceeded above ranges, the $\Delta P / L$ was modified, and the thickness ratio of burden material layers $x_1, x_2, ...x_6$ and the gas flow rate $u_1, u_2, \cdots u_6$ were recalculated, until the errors were in the selected ranges. When $\triangle P/L=1.545$ kpa/m finally, the calculation was stopped, and the final distribution of respective parameters in the radial direction of blast furnace throat was obtained. As shown in Table 3, Table 3 shows a comparative analysis of the parameters calculated in Example 1 of the present application and the parameters calculated theoretically.

Table 3 Comparative analysis of the parameters calculated in Example 1 of the present application and the parameters calculated theoretically

Convergence	X_t	0.5761	X_0	0.5692	ΔX	0.012122
	V_t	6090	V_0	6111	ΔV	-0.00344
	Q_t	799200	Q_0	828700	ΔQ	-0.0356

Example 2

Verification of the burden layer structure and gas flow rate distribution detection in practical blast furnace operation

[0070] In blast furnace 1# from Hongfa plant of Shagang group, during the period from December 1, 2013 to January 20, 2014, the quality of the raw material in the blast furnace was deteriorated, the slag ratio was increased to 320kg/t-HM, and M40 was reduced from 84 to 81. Although the raw material conditions were deteriorated, the operator allows the pressure drop of blast furnace to decrease through adjustment of the burden distribution matrix and the gas utilization rate was improved. Reference is made to Figure 6, which shows the operation condition of blast furnace with 2500m^3 in Hongfa plant according to the present application from the end of 2013 to the beginning of 2014, as shown in Figure 6. The main operating parameters vary from Case 1 to Case 5, and the specific parameters are as shown in Table 4.

Table 4 Change of main operating parameters of blast furnace with 2500m^3 in Hongfa plant from December 2013 to January 2014

operating interval	gas composition					temperature distribution						pressure drop (Kpa)
	CO (%)	CO_2(%)	H_2 (%)	N_2 (%)	η_{CO} (%)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	T5 (°C)	T6 (°C)	
case 1 (December 1, 2013 to December 6,2013)	20.34	18.93	2.82	56.4	48.2	527	289	110	81.4	85.7	141 .3	156.1
case 2 (December 7, 2013 to December 17, 2013)	20.76	18.98	2.77	55.9 9	47.76	638. 6	314	110	80.3	77.6	100 .5	155.6
case 3 (December 18, 2013 to December 25 2013)	21.1	18.9	2.58	55.8 9	47.2	632. 3	290 .5	99. 1	78.8	78.9	92. 8	150.3
case 4 (December 26, 2013 to January 2, 2014)	19.96	18.5	2.48	57.5 6	48.1	539	240	102	81.4	80	91. 5	152
case 5 (January 3, 2014 to January 20, 2014)	19.8	18.74	2.48 2	57.4 8	48.62	478	206 .7	91. 6	73.2	70.1	73. 8	152.7

[0071] Based on these five operating periods, the heat flow ratio distribution, thickness ratio of burden material layers distribution and gas flow rate distribution of respective temperature-measuring device regions in the radial direction of blast furnace throat within these five time periods were respectively calculated, and the changes of respective parameters before and after each change of the burden distribution matrix were compared. It is found that, the direction of each change of the burden distribution matrix is consistent with the direction of the distribution change of the ore layer thickness ratio calculated, and changes in the gas flow distribution and the temperature distribution accordingly are also the same as expected.

[0072] Specific analysis: reference is made to Figure 7, which shows the change of respective parameters from Case 1 to Case 2 according to the present application. As shown in Figure 7, from Case 1 to Case 2, the operator changes the burden distribution matrix from $C_{33222212}^{109876531} O_{14443}^{98765}$ to $C_{23222222}^{109876543} O_{24443}^{98765}$, wherein for $C_b{}^a$, C is the charge item of coke in the burden distribution matrix, a is the charging position, and b is the number of turns; for $O_b{}^a$, O is the charge item of ore in the burden distribution matrix, a is the charging position and b is the number of turns. Charging position 10 is close to the furnace wall, charging position 1 is the center of blast furnace, charging position 9 at an edge of the ore is changed from one turn to two turns. It can be inferred that, the ore layer thickness ratio at the edge increases and the gas flow rate at the edge decreases, which are consistent with the directions of distribution change of the calculated ore layer thickness ratio X_i and the calculated gas flow rate u_i.

[0073] Reference is made to Figure 8, which shows the change of respective parameters from Case 2 to Case 3 according to the present application. As shown in Figure 8, from Case 2 to Case 3, M40 is decreased significantly, the slag ratio is increased rapidly, the operator changes the burden distribution matrix from $C_{23222222}^{109876543} O_{24443}^{98765}$ to $C_{3222222}^{10987654} O_{24443}^{98765}$, 2 turns of coke is removed from the charging position 3. It can be inferred that, the coke in the corresponding middle part is increased and the layer thickness ratio of the ore is decreased, which are consistent with the change of the distribution of the calculated ore layer thickness ratio x_i.

[0074] Reference is made to Figure 9, which shows the change of respective parameters from Case 3 to Case 4 according to the present application. As shown in Figure 9, from Case 3 to Case 4, the operator changes the burden distribution matrix from $C_{3222222}^{10987654} O_{24443}^{98765}$ to $C_{2222222}^{10987654} O_{2233332}^{10987654}$, charging position 10 and charging position 4 of the ore are each provided with two turns. It can be inferred that, the ore layer thickness ratios of the center part and the center part are increased and the ore layer thickness ratio of the middle part is reduced, which are basically consistent with the calculated results.

[0075] Reference is made to Figure 10, which shows the change of respective parameters from Case 3 to Case 4 according to the present application. As shown in Figure 10, from Case 4 to Case 5, the operator changes the burden distribution matrix from $C_{2222222}^{10987654} O_{2233332}^{10987654}$ to $C_{2233322}^{10987654} O_{3233332}^{10987654}$ 3233332 , the intermediate charging positions "6", "7" and "8" of coke change from being provided with two turns to three turns. The ore layer thickness ratio at the corresponding middle part is reduced, which is consistent with the calculated result. In addition, charging position 10 of the ore changes from being provided with two turns to three turns, the ore layer thickness ratio at the corresponding edge is inferred to be increased, which is consistent with the calculated result.

[0076] From the above analysis, it can be seen that the accuracy of the method for detecting the gas flow distribution and the radial ore layer thickness radio in blast furnace according to the present application demonstrates the merit of this method for guiding the practical blast furnace operation.

[0077] The method for detecting gas flow distribution in blast furnace provided according to the present application has been described in detail hereinbefore. The principle and the embodiments of the present application are illustrated herein by specific examples. The above description of examples is only intended to help the understanding of the method according to the present application and the core spirit thereof. It should be noted that, for those skilled in the art, several modifications and improvements may be made to the present application without departing from the principle of the present application, and these modifications and improvements are also deemed to fall within the scope of the present application defined by the claims.

Claims

1. A method for detecting gas flow distribution in blast furnace, wherein the method comprises the following steps:

   a) dividing a cross-section of blast furnace throat according to the number and positions of temperature-meas-

uring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1;
b) obtaining a solid-gas heat flow ratio of each of the temperature-measuring device regions according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region;
c) establishing a function relation between a thickness ratio of burden material layers and a gas flow rate within each of the temperature-measuring device regions according to the solid-gas heat flow ratio of each of the temperature-measuring device regions;
d) obtaining the thickness ratio of burden material layers within each of the temperature-measuring device regions according to pressure drop per unit length of burden layer, particle size distribution of the burden materials and gas resistance equation of each lump zone of blast furnace, and obtaining the gas flow rate of each of the temperature-measuring device regions according to the thickness ratio of burden material layers within each of the temperature-measuring device region above and the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device region obtained in the above step c); and
e) plotting the region distribution of each of the temperature-measuring device regions and the gas flow rate thereof, to obtain a detection result of the gas distribution.

2. The method according to claim 1, wherein the method further comprises, after step d):

d#) obtaining by calculation an average thickness ratio of burden material layers according to the thickness ratio of burden material layers within each of the temperature-measuring device regions, and obtaining a total volume of gas flow passing through the temperature-measuring device regions according to gas flow rate in each of the temperature-measuring device regions, to further obtain a total heat of gas flow passing through the temperature-measuring device regions;
comparing the average thickness ratio of burden material layers obtained in the above step with a theoretical average thickness ratio of burden material layers, to obtain an error $\sigma 1$; comparing the total volume of gas flow passing through the temperature-measuring device regions obtained in the above step with a theoretical total volume of furnace top gas flow, to obtain an error $\sigma 2$; and comparing the total heat of gas flow passing through the temperature-measuring device regions with a theoretical total heat of furnace top gas flow, to obtain an error $\sigma 3$;
modifying the pressure drop per unit length of burden layer and the particle size distribution of burden materials if one or more of the errors $\sigma 1$, $\sigma 2$, and $\sigma 3$ has a value greater than or equal to 5%, and performing the step d) again, until the value of each of the errors $\sigma 1$, $\sigma 2$, and $\sigma 3$ is less than 5%; and
performing the above step e) if the value of each of the errors $\sigma 1$, $\sigma 2$, and $\sigma 3$ is less than 5%.

3. The method according to claim 2, wherein the burden materials are ore and coke, and the theoretical average thickness ratio of burden material layers is calculated based on the formula: $X_0=[L_O/(L_O+L_C)]_0$, wherein Lo is a thickness of ore layer, and Lc is a thickness of coke layer.

4. The method according to claim 2, wherein the thickness ratio of burden material layers within each of the temperature-measuring device regions is x_i, the average thickness ratio of burden material layers is X_t, and the average thickness ratio of burden material layers is calculated based on the formula:

$$X_t = \sum_{i=1}^{N} x_i \cdot S_i / A$$

wherein S_i is an area of each of the temperature-measuring device regions, and A is a total area of the cross-section of the blast furnace throat.

5. The method according to claim 1, wherein the burden materials are ore and coke, the thickness ratio of burden material layers in the temperature-measuring device region is x_i, the gas flow rate in the temperature-measuring device region is u_i, then the function relation between the thickness ratio of burden material layers and the gas flow rate in the temperature-measuring device region is:

$$x_i = (\frac{C_s G_s}{C_g G_g})_i \cdot \frac{(C_g)_i (\rho_g)_i}{C_s(\rho_O - \rho_C) v_i} u_i - \frac{\rho_C}{(\rho_O - \rho_C)}$$

wherein C_g is a specific heat of gas, C_s is a specific heat of solid, G_g is a flow rate of gas, G_s is a flow rate of solid, ρ is a density of furnace top gas , v is a descent velocity of a solid burden bed, ρ_O is a density of ore, and ρ_C is a density of coke.

6. The method according to claim 1, wherein the gas resistance equation of each lump zone of blast furnace is:

$$(\frac{\Delta P}{L})_i = [k_1^* \frac{(1-\varepsilon)^2}{D_p^2 \varepsilon^3} \cdot \mu u + k_2^* \frac{(1-\varepsilon)}{D_p \varepsilon^3} \rho u^2]_i$$

wherein, k_1* is a viscous resistance coefficient, k_2* is an inertia resistance coefficient, $\Delta P/L$ is a pressure drop per unit length, ε is a burden bed porosity, D_p an average particle diameter of particles, μ is a gas viscosity, u is a gas flow rate, and ρ is a gas density;

the viscous resistance coefficient and the inertia resistance coefficient of the coke are respectively:

$$k_1^* = 450 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 2.2 \cdot (D_p \cdot 10)^{0.04};$$

the viscous resistance coefficient and the inertia resistance coefficient of the ore are respectively:

$$k_1^* = 260 \cdot (D_p \cdot 10)^{0.84}, k_2^* = 1.2 \cdot (D_p \cdot 10)^{0.04}.$$

7. The method according to claim 1, wherein the pressure drop per unit length of burden layer in each lump zone of blast furnace is equal,

the pressure drop per unit length of burden layer in each lump zone of blast furnace is equal to the sum of a pressure drop per unit length of coke layer and a pressure drop per unit length of ore layer in said lump zone of blast furnace.

8. The method according to claim 1, wherein the temperature-measuring device is a cross-shaped temperature-measuring gun.

9. A system for detecting gas flow distribution in blast furnace, wherein the system comprises:

a division unit, configured to divide a cross-section of blast furnace throat according to the number and positions of temperature-measuring devices at the top of blast furnace to obtain N temperature-measuring device regions; wherein the N is a natural number greater than or equal to 1;

a first attainment unit, configured to obtain a solid-gas heat flow ratio of each of the temperature-measuring device regions according to temperature values from each of the temperature-measuring devices and a balance equation between a heat flow rate of gas and a heat flow rate of solid in a lump zone of blast furnace below corresponding temperature-measuring device region;

an establishment unit, configured to establish a function relation between a thickness ratio of burden material layers and a gas flow rate within each of the temperature-measuring device regions according to the solid-gas heat flow ratio of each of the temperature-measuring device regions;

a second attainment unit, configured to obtain the thickness ratio of burden material layers within each of the temperature-measuring device regions according to pressure drop per unit length of burden layer, particle size distribution of the burden materials and gas resistance equation of each lump zone of blast furnace, and to obtain the gas flow rate of each of the temperature-measuring device regions according to the thickness ratio of burden material layers within each of the temperature-measuring device region above and the function relation between the thickness ratio of burden material layers and the gas flow rate within each of the temperature-measuring device region obtained in the above step c); and a result unit, configured to plot the above distribution of each of the temperature-measuring device regions and the gas flow rate thereof, to obtain a detection result of the gas distribution.

10. The detection system according to claim 9, wherein the system further comprises:

a verification unit, configured to obtain by calculation an average thickness ratio of burden material layers according to the thickness ratio of burden material layers within each of the temperature-measuring device regions, and to obtain a total volume of gas flow passing through the temperature-measuring device regions according to gas flow rate in each of the temperature-measuring device regions, to further obtain a total heat of gas flow passing through the temperature-measuring device regions;
wherein the average thickness ratio of burden material layers obtained in the above step is compared with a theoretical average thickness ratio of burden material layers, to obtain an error σ1; the total volume of gas flow passing through the temperature-measuring device regions obtained in the above step is compared with a theoretical total volume of furnace top gas flow, to obtain an error σ2; and the total heat of gas flow passing through the temperature-measuring device regions is compared with a theoretical total heat of furnace top gas flow, to obtain an error σ3;
the pressure drop per unit length of burden layer and the particle size distribution of burden materials are modified if one or more of the errors σ1, σ2, and σ3 has a value greater than or equal to 5%, and the step d) is performed again, until the value of each of the errors σ1, σ2, and σ3 is less than 5%; and
the step e) is performed in the case that the value of each of the errors σ1, σ2, and σ3 is less than 5%.

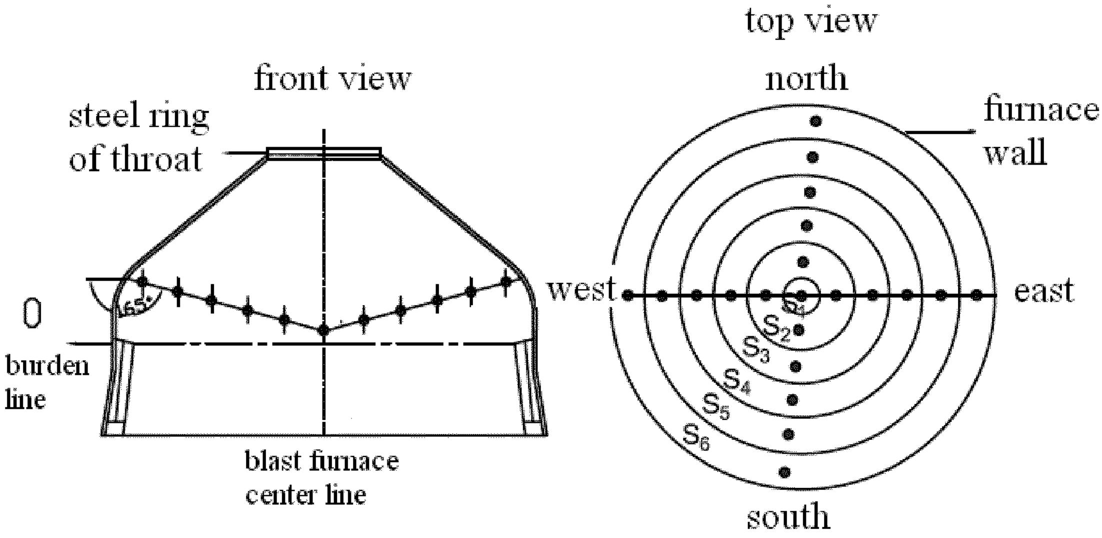
front view
steel ring of throat
0
65°
burden line
blast furnace center line
top view
north
furnace wall
west
east
S1
S2
S3
S4
S5
S6
south

Fig. 1

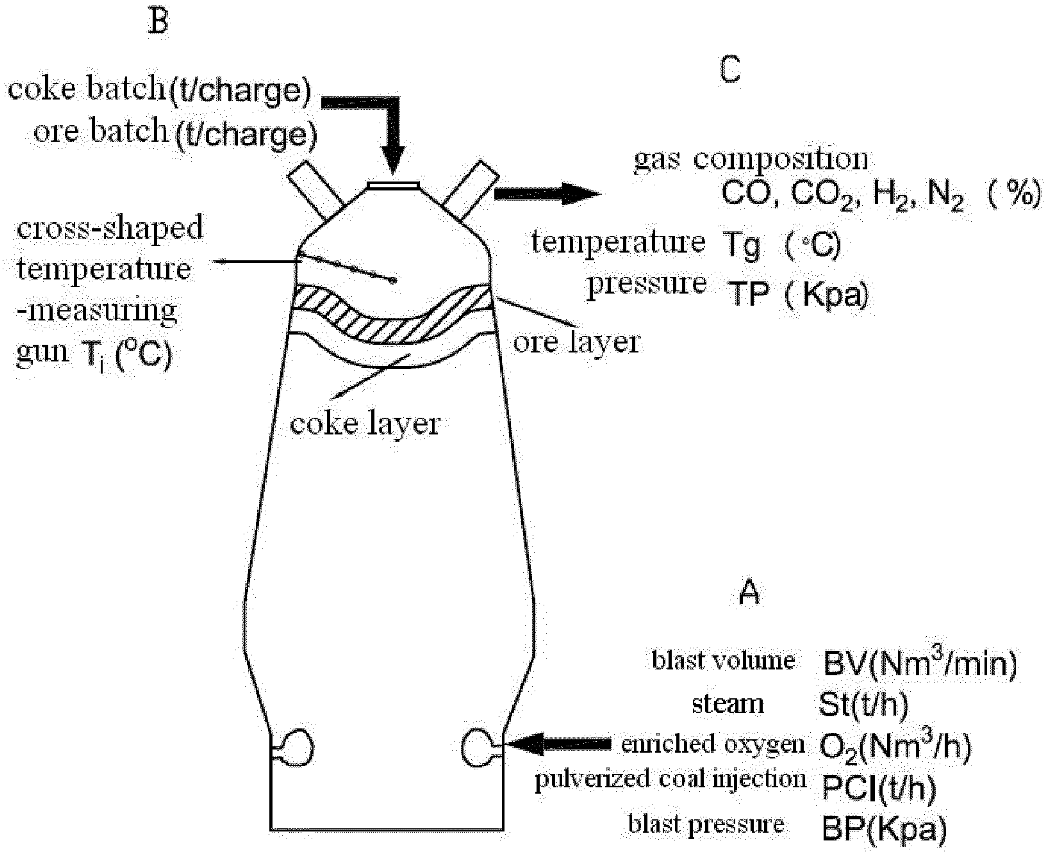
B
coke batch(t/charge)
ore batch (t/charge)
C
gas composition
CO, CO2, H2, N2 (%)
temperature Tg (°C)
pressure TP (Kpa)
cross-shaped temperature -measuring gun Ti (°C)
ore layer
coke layer
A
blast volume BV(Nm3/min)
steam St(t/h)
enriched oxygen O2(Nm3/h)
pulverized coal injection PCI(t/h)
blast pressure BP(Kpa)

Fig. 2

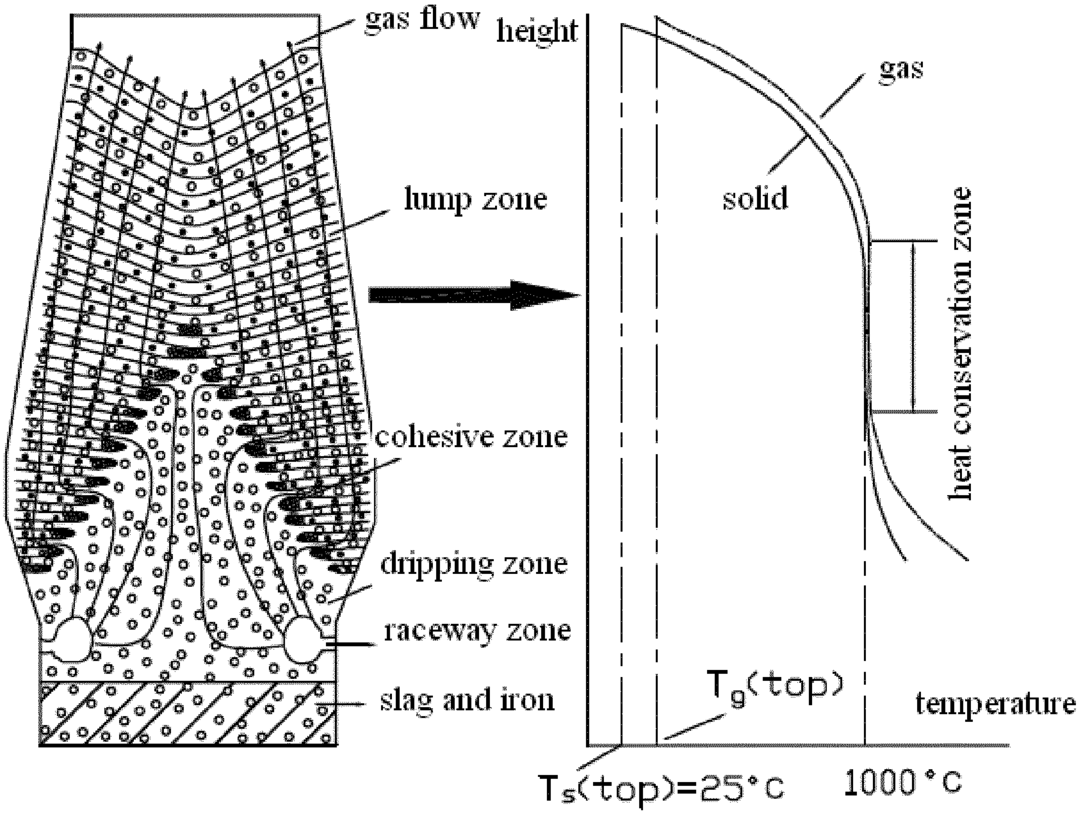
gas flow
lump zone
cohesive zone
dripping zone
raceway zone
slag and iron
height
gas
solid
heat conservation zone
T_g(top)
temperature
T_s(top)=25°c
1000°c

Fig. 3

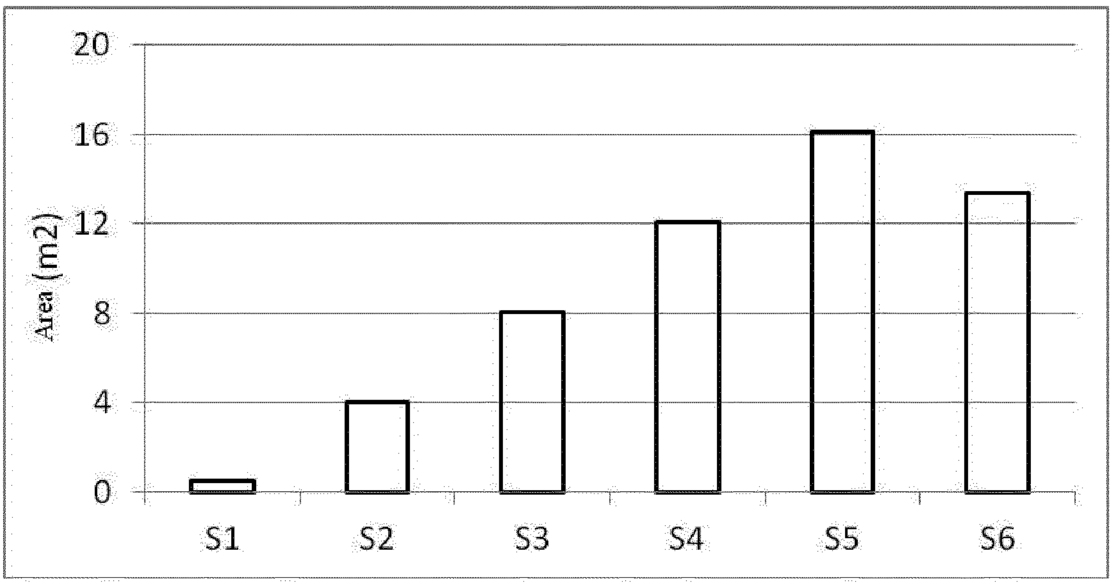
20
16
12
8
4
0
Area (m2)
S1
S2
S3
S4
S5
S6

Fig. 4

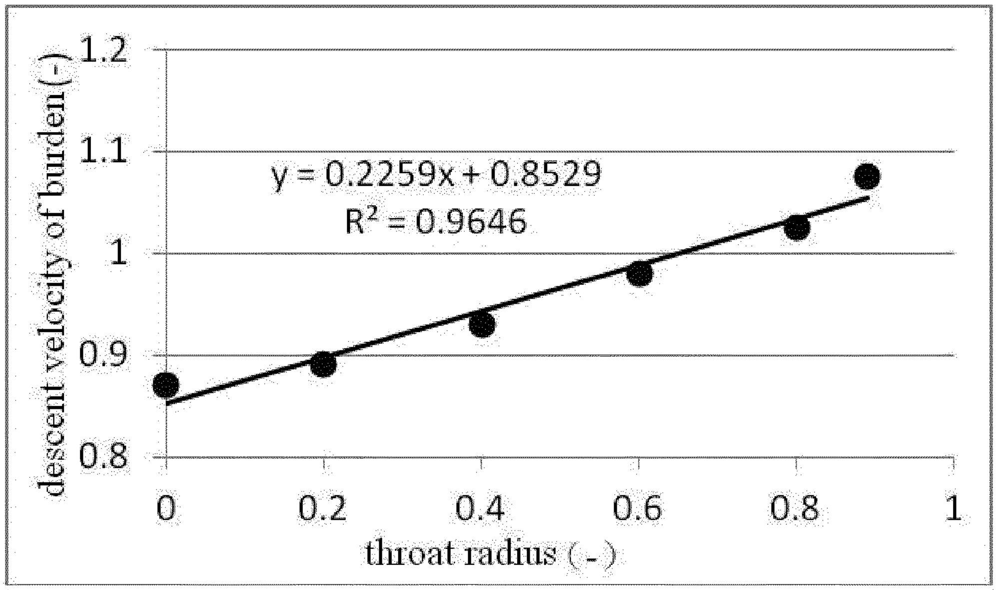
y = 0.2259x + 0.8529
R² = 0.9646
descent velocity of burden (-)
throat radius (-)
1.2
1.1
1
0.9
0.8
0
0.2
0.4
0.6
0.8
1

Fig. 5

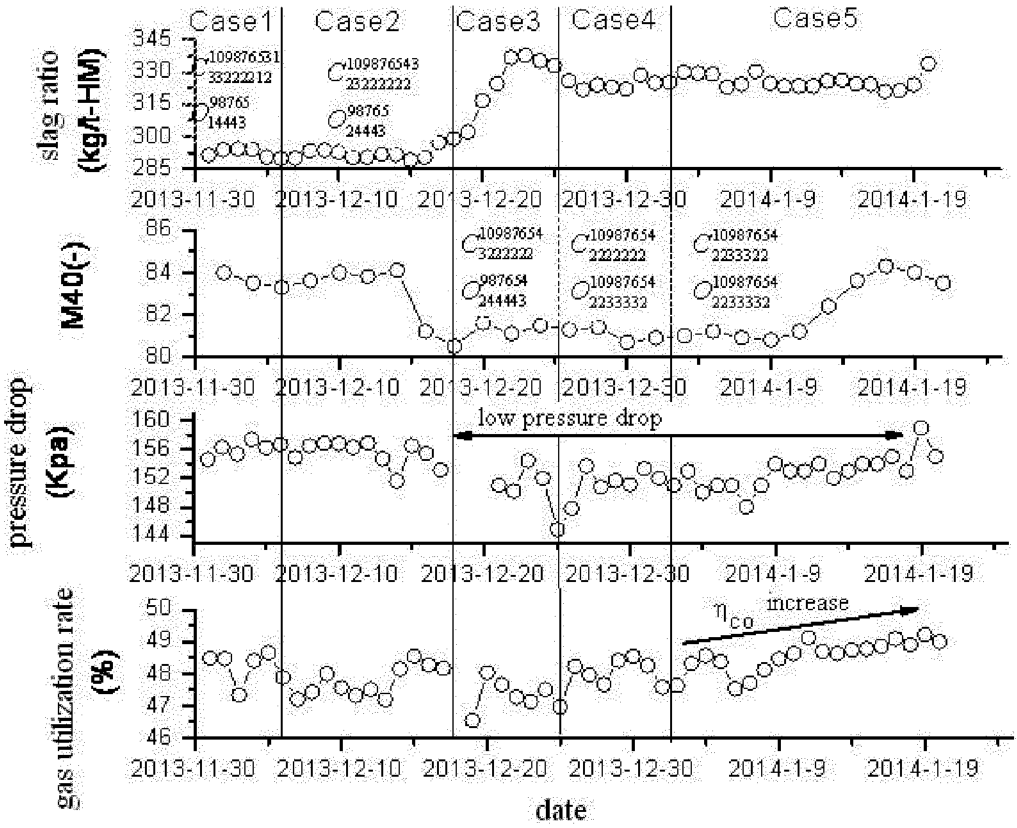
Case1
Case2
Case3
Case4
Case5
slag ratio (kg/t-HM)
M40(-)
pressure drop (Kpa)
gas utilization rate (%)
low pressure drop
ηco increase
2013-11-30
2013-12-10
2013-12-20
2013-12-30
2014-1-9
2014-1-19
date

Fig. 6

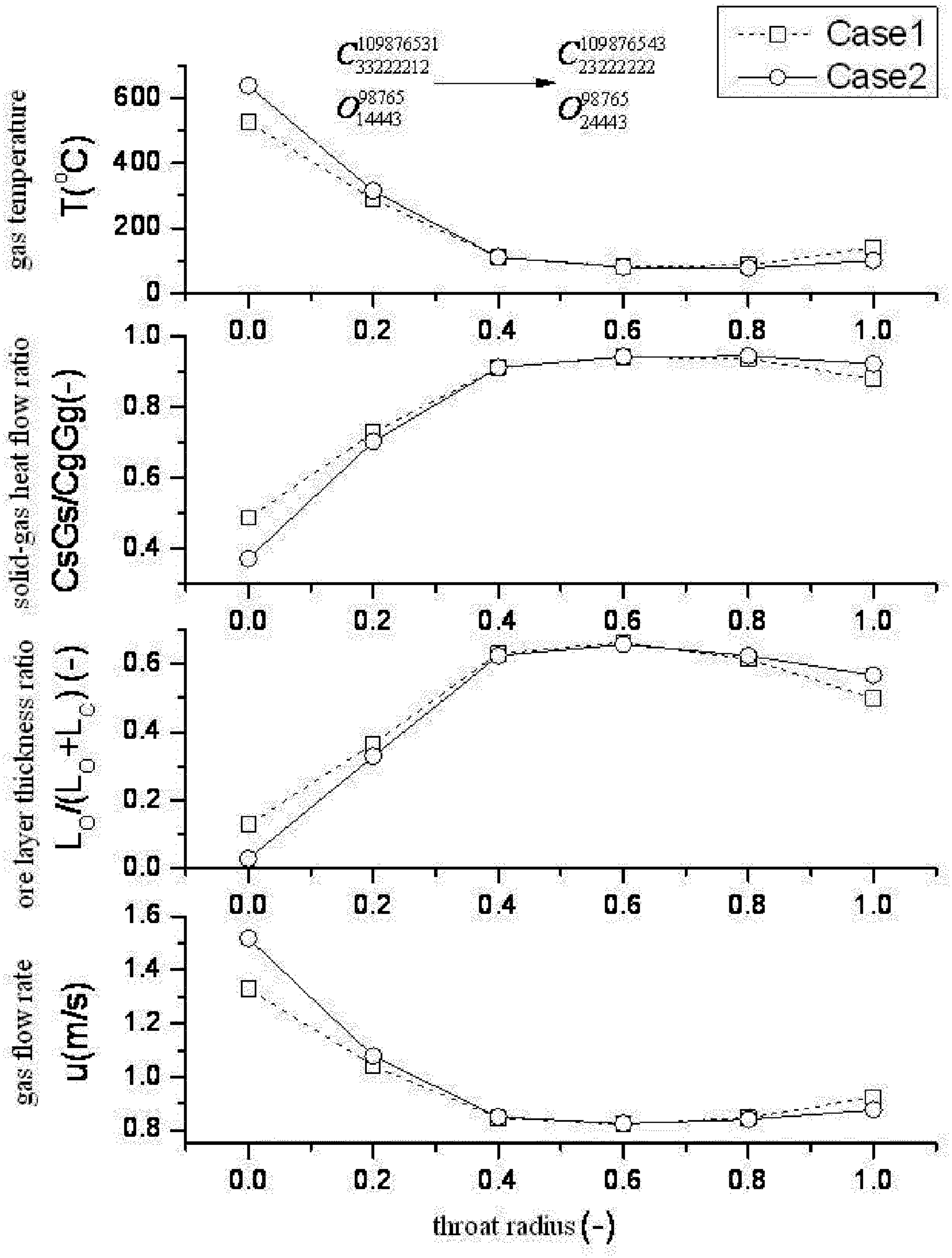
Case1
Case2
$C^{109876531}_{33222212}$
O^{98765}_{14443}
$C^{109876543}_{23222222}$
O^{98765}_{24443}
gas temperature
T(°C)
600
400
200
0
0.0
0.2
0.4
0.6
0.8
1.0
solid-gas heat flow ratio
CsGs/CgGg(-)
1.0
0.8
0.6
0.4
ore layer thickness ratio
$L_O/(L_O+L_C)$ (-)
0.6
0.4
0.2
0.0
gas flow rate
u(m/s)
1.6
1.4
1.2
1.0
0.8
throat radius (-)

Fig. 7

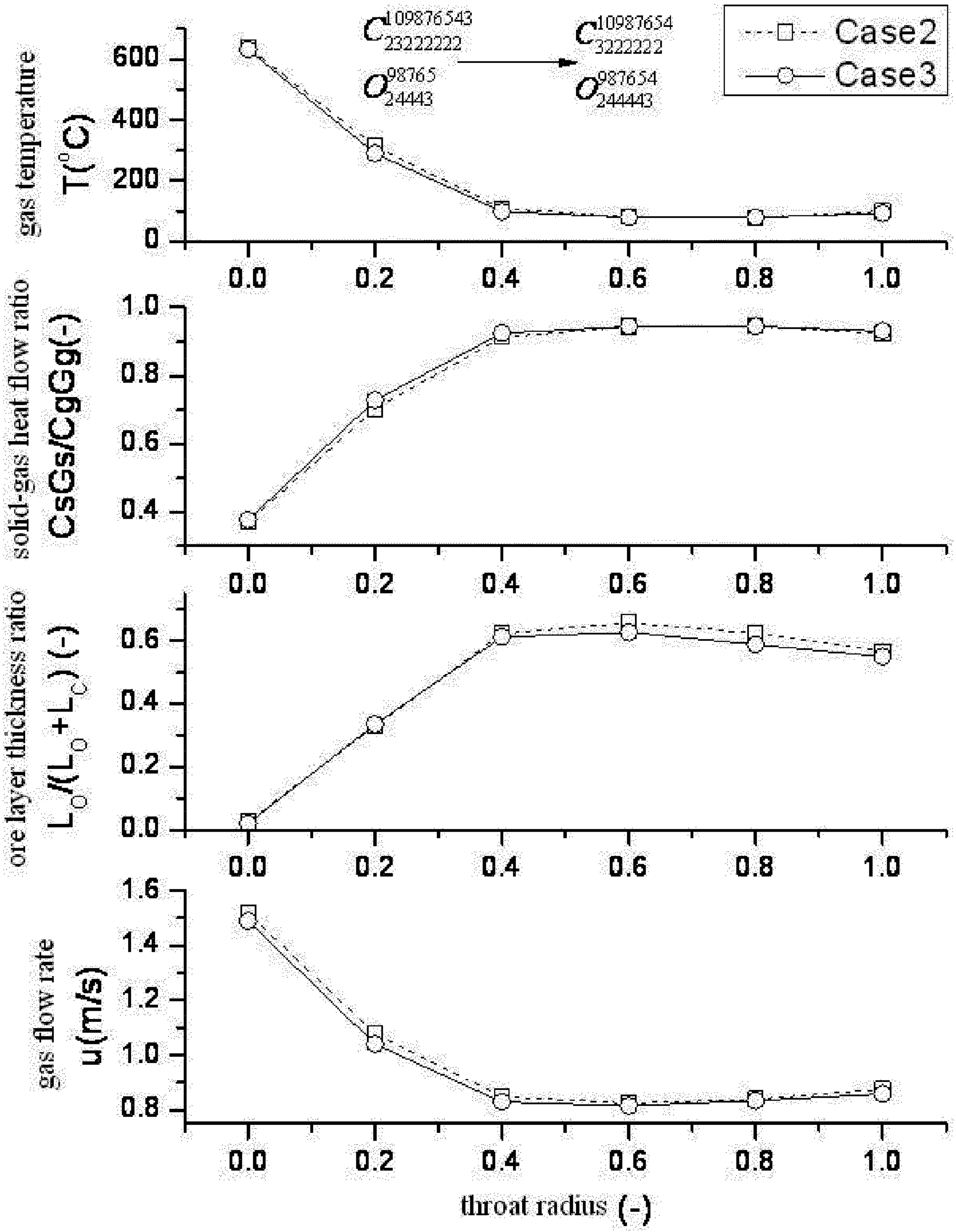
Case2
Case3
gas temperature
T(°C)
solid-gas heat flow ratio
CsGs/CgGg(-)
ore layer thickness ratio
L_O/(L_O+L_C) (-)
gas flow rate
u(m/s)
throat radius (-)

Fig. 8

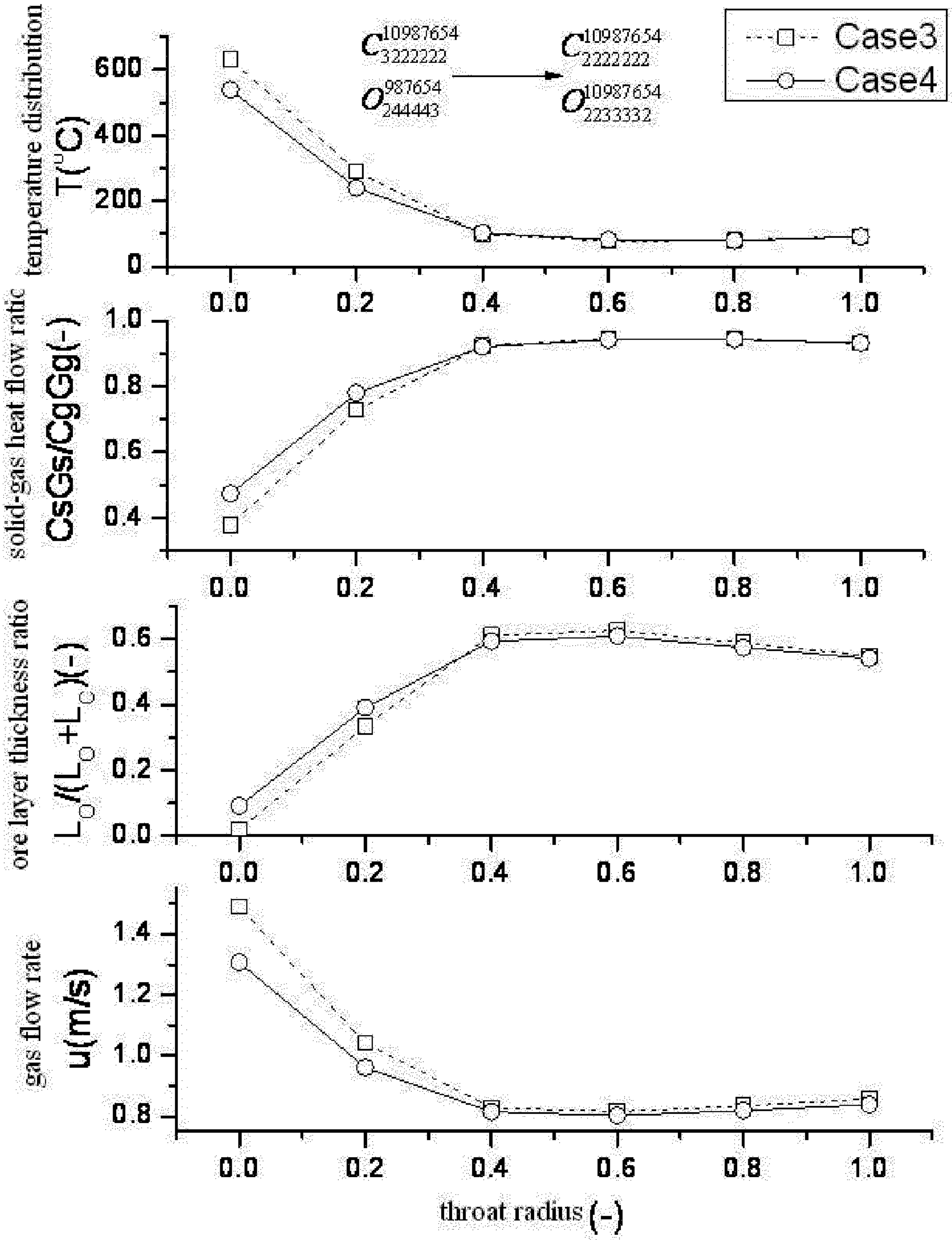
Case3
Case4
temperature distribution
T(°C)
solid-gas heat flow ratio
CsGs/CgGg(-)
ore layer thickness ratio
$L_O/(L_O+L_C)$(-)
gas flow rate
u(m/s)
throat radius (-)

Fig. 9

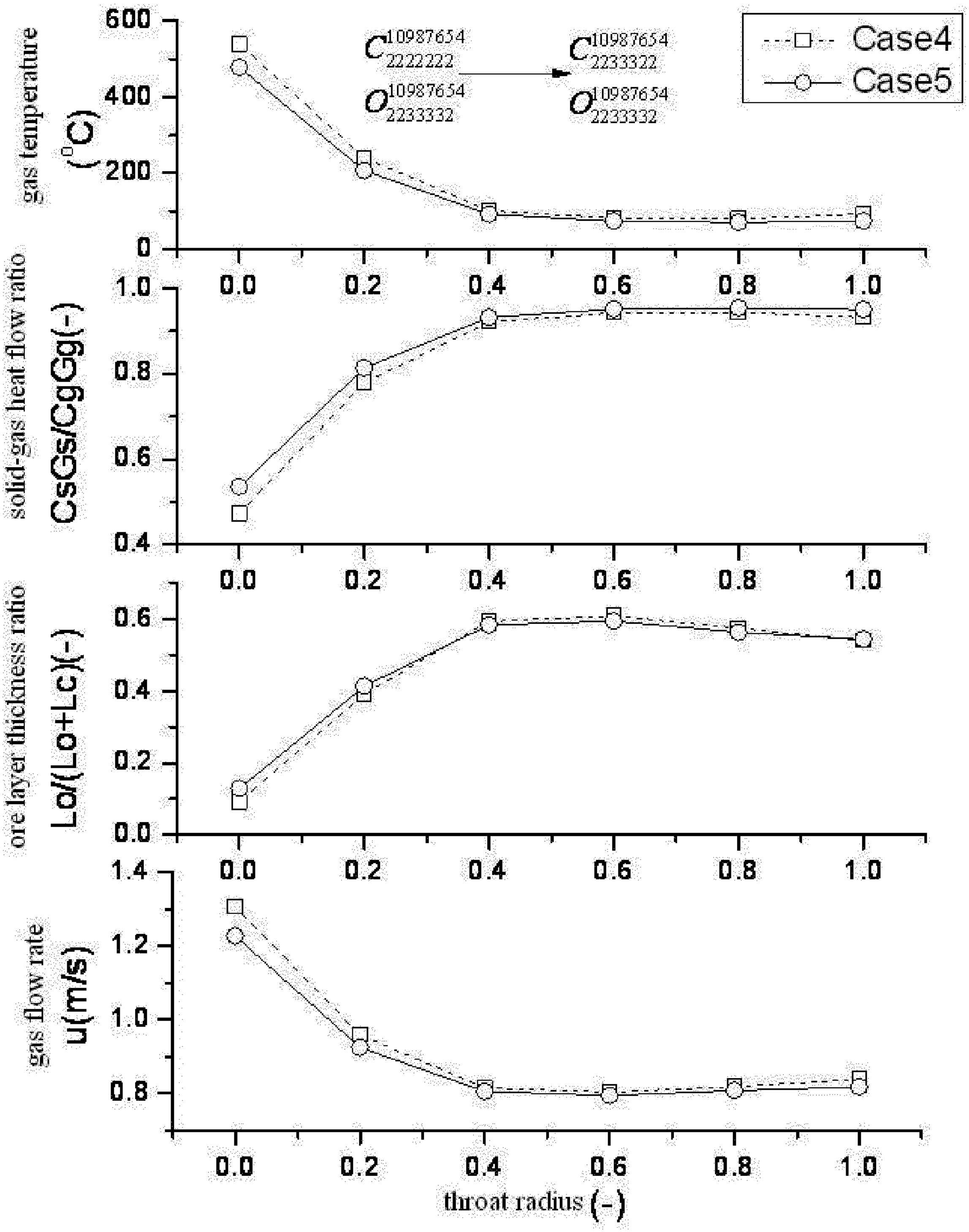
600
400
200
0
gas temperature
(°C)
$C^{10987654}_{2222222}$
$O^{10987654}_{2233332}$
$C^{10987654}_{2233322}$
$O^{10987654}_{2233332}$
Case4
Case5
solid-gas heat flow ratio
CsGs/CgGg(-)
1.0
0.8
0.6
0.4
ore layer thickness ratio
Lo/(Lo+Lc)(-)
0.6
0.4
0.2
0.0
gas flow rate
u(m/s)
1.4
1.2
1.0
0.8
0.0
0.2
0.4
0.6
0.8
1.0
throat radius (-)

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2014/086931

A. CLASSIFICATION OF SUBJECT MATTER

C21B 5/00 (2006.01) i; C21B 7/24 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

VEN, CPRS, CNKI: gas flow+, distribut+, detect+, measur+, temperatur+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010209404 A (KAWASAKI STEEL CORP.), 24 September 2010 (24.09.2010), the whole document	1-10
A	JP 57-149403 A (KAWASAKI STEEL CORP.), 16 September 1982 (16.09.1982), the whole document	1-10
A	JP 55-69208 A (KAWASAKI STEEL CO.), 24 May 1980 (24.05.1980), the whole document	1-10
A	JP 10-206239 A (SUMITOMO METAL IND LTD.), 07 August 1998 (07.08.1998), the whole document	1-10
A	SU 1201314 A (FERR METALLURGY AUTOMN et al.),30 December 1985 (30.12.1985), the whole document	1-10
A	KR 20000013124 A (POHANG IRON & STEEL CO., LTD.), 06 March 2000 (06.03.2000), the whole document	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 May 2015 (14.05.2015)	**05 June 2015 (05.06.2015)**

Name and mailing address of the ISA/CN:
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Telephone No.: (86-10) **62084745**

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2014/086931

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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SU 1201314 A	30 December 1985	None	
KR 20000013124 A	06 March 2000	None	

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 201410446536 **[0001]**
- SU 1330163 **[0006]**

Non-patent literature cited in the description

- Radial distribution of Burden Descent Velocity near Burden Surface in Blast Furnace. ICHIDA in ISIJ international, 1996, vol. 36, 493-502 **[0061]**