[0006]

The invention aims to solve the above problems, and to provide a combustion method for a fluidized bed boiler, and a fluidized bed boiler that can improve energy recovery efficiency while preventing poor fluidity, even in a case where fuel containing alkaline components is used.

Solution to Problem

[0007]

A refining slag produced by the refining of an ore, for example, a ferronickel slag, has only an application of being used as pavement, and is normally disposed of. The present inventor focused on the ferronickel slag that is a kind of refining slag, containing about 30% (wt.% concentration) of magnesium oxide, and intensively studied effective use of the refining slag. As a result, the inventor obtained the knowledge that, if the ferronickel slag is added to a fluidized bed boiler, poor fluidity can be effectively prevented, and have derived the invention.

[0008]

That is, the invention provides a combustion method for a fluidized bed boiler using fuel containing alkaline components. The method includes adding a refining slag produced by refining of an ore in addition to the fuel, and burning the fuel in the fluidized bed

boiler.

[0009]

In a case where fuel containing alkaline components, such as biomass fuel, is used as the fuel for the fluidized bed boiler, alkali silicate is formed by a chemical reaction between alkaline components, such as potassium (K) or sodium (Na), and quartz particles serving as fluidized material components. This alkali silicate, which is a low melting-point compound that melts at about 700°C, may form an adhesion layer on the surface of particles serving as the fluidized material, and may obstruct the fluidization of the fluidized material. However, in the invention, the refining slag is supplied to the fluidized bed boiler in addition to the fuel containing alkaline components, and magnesium oxide is contained in the refining slag. Therefore, generation of alkali silicate can be suppressed. Accordingly, a possibility that poor fluidity may occur in conjunction with generation of low-melting-point compounds decreases and the operation of the fluidized bed boiler at high temperatures is possible. As a result, it becomes easier to improve energy recovery efficiency. Moreover, since magnesium carbonate or magnesium hydroxide is not contained but magnesium oxide is contained in the refining slag, the magnesium oxide contributes directly to suppression of generation of alkali silicate. Thus, high energy recovery efficiency can be expected compared to the case where magnesium carbonate or magnesium

hydroxide is added.

[0010]

Moreover, preferably, a refining slag is used as the fluidized material of the fluidized bed boiler. Since a fluidized bed can be formed using the refining slag, poor fluidity of the fluidized bed can be effectively suppressed without any bias.

[0011]

Moreover, preferably, the fluidized bed boiler includes a furnace body, a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas, a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing a back flow from the furnace body, and the refining slag is supplied to the circulation seal section. Poor fluidity in the circulation seal section can be effectively deterred.

[0012]

Additionally, the invention provides a fluidized bed boiler using fuel containing alkaline components, the fluidized bed boiler including a furnace body that burns fuel to which a refining slag produced by the refining of an ore is added. According to the invention, even in a case where fuel containing alkaline components is used,

improvement in energy recovery efficiency and prevention of poor fluidity can be made compatible.

[0013]

Moreover, preferably, the refining slag serving as the fluidized material is put into the furnace body. According to this configuration, since a fluidized bed can be formed using the refining slag, poor fluidity of the fluidized bed can be effectively suppressed without any bias.

[0014]

Moreover, preferably, the fluidized bed boiler further includes a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas, and a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing a back flow from the furnace body, and the refining slag is supplied to the circulation seal section. According to this configuration, poor fluidity in the circulation seal section can be effectively deterred.

Advantageous Effects of Invention

[0015]

According to the invention, in a case where fuel containing

alkaline components is used as the fuel for the fluidized bed boiler, improvement in energy recovery efficiency and prevention of poor fluidity can be made compatible.

Brief Description of Drawings

[0016]

FIG. 1 is an explanatory view schematically showing a fluidized bed boiler.

FIGS. 2A and 2B are explanatory views showing a generation mechanism of agglomerate; FIG. 2A is a view illustrating a coating inducing mechanism, and FIG. 2B is a view illustrating a melting inducing mechanism.

FIG. 3 is a K_2O–SiO_2 phase diagram.

FIG. 4 is an MgO–SiO_2 phase diagram.

FIG. 5 is an MgO–K_2O–SiO_2 phase diagram.

FIG. 6 is an explanatory view schematically showing a phase where MgO acts on eutectic coating C.

FIG. 7 is a view illustrating the properties of three samples that are ferronickel slags.

FIG. 8 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where a ferronickel slag is added.

FIG. 9 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where a

ferronickel slag is not added (no addition).

Description of Embodiments

[0017]

A preferred embodiment of a fluidized bed boiler and a combustion method for a fluidized bed boiler related to the invention will be described below, referring to the drawings.

[0018]

As shown in FIG. 1, the fluidized bed boiler (hereinafter referred to as "a CFB boiler") 1 includes a combustion tower (furnace body) 3 that burns fuel to heat the water in an airtight container to generate steam, a cyclone separator (separation section) 5 that separates solids from combustion gas (hereinafter referred to as "exhaust gas") G produced in the combustion tower 3, a heat recovery section 7 that recovers the heat of the exhaust gas G, a circulation line 9 through which fly ash separated from the exhaust gas G in the cyclone separator 5, i.e., a fluidized material Fa (refer to FIG. 2) separated from the exhaust gas G, is returned to a lower part of the combustion tower 3, and the like. In addition, a heat exchange tube, such as a superheater, is arranged in the heat recovery section 7.

[0019]

Biomass fuel, such as rice husk or EFB (Empty Fruit Bunches),

is put into the combustion tower 3. This kind of biomass fuel is low-grade fuel containing a number of alkaline components, such as potassium or sodium. Moreover, a ferronickel slag that is a kind of refining slag is put into the combustion tower 3. The fluidized material Fa composed mainly of quartz particles is put into the combustion tower 3, air is supplied into the fluidized material Fa from a lower part of the combustion tower, and the fluidized material Fa is fluidized to form a fluidized bed (hereinafter referred to as a "bed") F. Combustion of fuel is promoted through the formation of the bed F. The exhaust gas G produced as a result of the combustion goes up within the combustion tower 3 while accompanying a portion of the fluidized material Fa. In addition, although an aspect in which the ferronickel slag is added into the fluidized material Fa has been described in the present embodiment, it is also possible to use the ferronickel slag itself as the fluidized material Fa.

[0020]

The cyclone separator 5 is arranged adjacent to the combustion tower 3, receives the exhaust gas G exhausted from the combustion tower 3 and the fluidized material Fa accompanied by the exhaust gas G, and separates the exhaust gas G and the fluidized material Fa due to a centrifugation action to return the fluidized material Fa to the combustion tower 3, and send the exhaust gas G into the heat recovery section 7.

[0021]

The circulation line 9 is connected to the cyclone separator 5. The circulation line 9 consists of a line connected to the lower part of the combustion tower 3, and a loop seal (circulation seal section) 9a is provided on the circulation line 9. The loop seal 9a is a facility that prevents back flow of the exhaust gas G from the combustion tower 3, and the fluidized material Fa sent in from the cyclone separator 5 is accumulated in the loop seal 9a, and the fluidized material Fa is put into the combustion tower 3 from a return chute section 9b at an outlet of the loop seal 9a.

[0022]

Additionally, the CFB boiler 1 includes a refining slag supply section 11 for supplying the ferronickel slag that is a kind of refining slag into the loop seal 9a. By supplying the ferronickel slag into the loop seal 9a, poor fluidity within the loop seal 9a can be effectively suppressed.

[0023]

Next, a phenomenon that occurs when biomass fuel is put into the CFB boiler 1 and is burned will be described.

[0024]

The concept of generation of bottom ash and fly ash in the combustion of the biomass fuel will be described. The bottom ash is formed as particles as components in the biomass fuel condense, melt, agglomerate, and adhere with sand that is the fluidized material Fa acting as a seed, or react chemically on the sand surface. Additionally, the fly ash is formed by the condensation, melting, and agglomeration of the components in the biomass fuel itself if fine components are removed from some of the bottom ash that is formed as particles.

[0025]

A major cause of fluidization impediment in the fluidized material (also referred to as "fluidized sand" or "bed material") Fa in the combustion of the biomass fuel is an agglomerate X (refer to FIG. 2). It is considered that that most of the agglomerate X is produced as the melt (the melt of substance formed by the components in the biomass fuel) of low melting-point compounds adheres to the surface of the fluidized material Fa, or is eutectically formed on the surface of the fluidized material Fa (the components in the biomass fuel chemically react on the surface of the fluidized material Fa), and is generated due to two mechanisms known as melting inducement and coating inducement.

[0026]

Specifically, the major cause of generation of the agglomerate

X when the biomass fuel is burned is specified to be due to the fact that a chemical reaction is caused between the alkaline components from the biomass fuel, for example, potassium, (K), sodium (Na), or the like and quartz particles that are principal components of the fluidized material Fa, and an adhesive alkali silicate layer is formed on the surface of the fluidized material Fa. In addition, in addition to the alkaline components, it is confirmed that phosphor is also an important factor in the agglomerate X.

[0027]

(Melting Inducing Mechanism)

As shown in FIG. 2B, the agglomerate X of the melting inducing mechanism is produced as bottom ash particle groups, in which the melt M of the low melting-point compounds (alkali silicate) has adhered to the surface of the fluidized material Fa, gather together. The control factors of this mechanism are local temperature and fuel ash composition. In the combustion ash containing high-concentration alkaline components and chlorine, the agglomerate X tends to be formed through the melting inducing mechanism.

[0028]

(Coating Inducing Mechanism)

As shown in FIG. 2A, as for the agglomerate X of the coating inducing mechanism, the bottom ash particle groups, in which eutectic

coating (alkali silicate phase) C on the surface of the fluidized material Fa is formed, are repeatedly joined and separated by the eutectic coating C thereof. As a result, particle agglomeration is started, which results in the formation of the agglomerate X that gradually becomes a neck (fluidization obstruction factor). The major control factors of this mechanism are eutectic coating thickness (ease of joining and separation), eutectic coating composition (joining strength), and local temperature.

[0029]

In addition, it has been confirmed from the detailed analysis results of a portion that is actually the coated surface of the fluidized material Fa that this coating layer is eutectic coating (K_2O-SiO_2: alkali silicate layer) C. As shown in FIG. 3, this eutectic coating C begins to melt at 700°C. It can be confirmed that particles that are the fluidized material Fa are caused to easily adhere and agglomerate to each other at a temperature in the fluidized material Fa of the CFB boiler 1, specifically, at 800°C to 900°C. In addition, FIG. 3 is a K_2O-SiO_2 phase diagram.

[0030]

Next, the relationship between the formation of the agglomerate X and magnesium oxide (MgO) will be described with reference to FIGS. 4 and 5. FIG. 4 is an MgO-SiO_2 phase diagram, and FIG. 5 is an

$MgO-K_2O-SiO_2$ phase diagram. In addition, as shown in FIG. 3, a straight line La of FIG. 5 shows the process in which MgO is obtained from the phase of $K_2O-4SiO_2$, and an arrow Da shows a direction in which the ratio of MgO increases.

[0031]

A foremost reaction phase (a first reaction phase), as shown in FIG. 3, is produced at a low temperature of about 700°C. In this first reaction, coating or the like is formed in the form of $K_2O-4SiO_2$ (refer to FIG. 3). Next, in a second reaction phase, a reaction proceeds in the direction of an arrow Da of FIG. 5, and MgO reacts little by little with $K_2O-4SiO_2$ formed in the first reaction phase. If the phase where the reaction of MgO has proceeded is seen on the straight line La (refer to FIG. 5), a first point Pb where the ratio of MgO is several percent (about 4 %) and the melting temperature is 742°C is reached, whereby the melting point is raised (a third reaction phase). Next, a second point Pa where the ratio of MgO is about 8 % and the melting temperature is 1000°C is reached, whereby the melting point is raised, and a layer with little adhesion is formed (a fourth reaction phase).

[0032]

MgO does not easily react above the second point Pa. This is because the melting point becomes 1000°C or higher and solids are produced, so a reaction with MgO (solids) is not easily caused. Here, if K_2O adheres again, for example, the phase returns to the first point Pb from the second point Pa, and 742°C becomes the melting point where adhesion becomes apt to occur. Next, the phase returns to the second

reaction phase where MgO reacts, and the third reaction phase and the fourth reaction phase are repeated again.

[0033]

As shown in FIG. 4, in the reaction of MgO and SiO_2, it is easily inferred that melt is not formed up to 1543°C. Additionally, as shown in FIG. 5, even in the reaction of MgO and K_2O–SiO_2, it is inferred that melt is formed up to about 1000°C. Accordingly, when biomass fuel containing a lot of alkaline components is burned, formation of eutectic coating (K_2O–SiO_2: alkali silicate phase) C with a low melting point can be suppressed by adding magnesium oxide into the fluidized material Fa.

[0034]

Here, suppressing the formation of the eutectic coating C with a low melting point will be structurally described with reference to FIG. 6. FIG. 6 is an explanatory view schematically showing a phase where MgO acts on the eutectic coating C. If the eutectic coating C is formed on the surface of the fluidized material Fa as shown in FIG. 6, an MgO–K_2O–SiO_2 layer S with a high melting point is formed and solidified on the surface, and the melting point is raised. Additionally, even if the eutectic coating C is formed on the surface of the layer, the MgO–K_2O–SiO_2 layer S with a high melting point is formed and solidified, and the melting point is raised. As a result,

even if the eutectic coating C with a low melting point is formed, the $MgO-K_2O-SiO_2$ layer S with a high melting point is formed on the surface of the eutectic coating C, and the melting point is kept from being lowered.

[0035]

Next, the refining slag, such as a ferronickel slag, will be described. The refining slag is a slag that is produced, for example, when refining a ferroalloy raw ore to generate ferroalloy. As a refining method, various methods, such as an electric furnace method or a thermite process can be applied. For example, in the electric furnace method, refining treatment in an electric furnace is performed after pretreatment of the raw ore, and the residue that remains after a desired metal is extracted in the refining treatment becomes a refining slag. In the present embodiment, a ferronickel slag is illustrated as the refining slag.

[0036]

FIG. 7 is a view illustrating the properties of three samples that are ferronickel slags. For example, magnesium oxide (MgO) with 28.1% wt.% concentration is contained in Sample A, 35.5% of magnesium oxide (MgO) is contained in Sample B, and about 50.0% to 55% of magnesium oxide (MgO) is contained in Sample C. As such, at least 30% or more of magnesium oxide is contained in the ferronickel slag. Accordingly,

it is inferred that the ferronickel slag is supplied into the combustion tower 3 of the CFB boiler 1, so that the formation of the agglomerate X can be suppressed, and poor fluidity can be effectively suppressed.

[0037]

Next, the combustion method for the CFB boiler 1 in a case where low-grade biomass fuel is used as boiler fuel will be described. The fluidized material Fa that forms the bed F has already been put into the combustion tower 3 of the CFB boiler 1. A ferronickel slag is supplied into the combustion tower 3 in addition to the biomass fuel, and combustion is caused by a burner (not shown) while air is supplied from the lower part of the fluidized material Fa to form the bed F. By adding the ferronickel slag into the fluidized material Fa in the combustion tower 3, magnesium oxide in the ferronickel slag can contribute to suppression of the formation of the agglomerate X and effective suppression of poor fluidity of the bed F.

[0038]

Here, the effects in a case where the ferronickel slag is added will be described with reference to FIGS. 8 and 9, as compared to a case where the ferronickel slag is not added. In addition, FIG. 8 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where the ferronickel slag is added, and FIG. 9 is a graph showing the

relationship between operating time, bed temperature, and bed differential pressure, in a case where the ferronickel slag is not added (no addition). In addition, the bed differential pressure shows pressure differential at upper and lower positions in the bed F that is being fluidized, and if poor fluidity occurs, the bed differential pressure drops abruptly and becomes "0" ultimately. Additionally, in the experimental conditions shown in FIGS. 8 and 9, the concentration of potassium contained in the bed F in the case where the ferronickel slag is not added is 0.6 wt% (ash base), whereas the concentration of potassium (K) contained in the bed F is as high as 2.6 wt% (ash base) in the case where the ferronickel slag is not added. Accordingly, the case where the ferronickel slag is not added becomes the environment in which the agglomerate X is easily formed.

[0039]

As shown in FIG. 8, in the case where the ferronickel slag is added, even if the bed temperature exceeds 800°C, it can be determined that there is no great change in the bed differential pressure and fluidity is good. On the other hand, as shown in FIG. 9, in the case where the ferronickel slag is not added, since the bed temperature exceeds 800°C, and the bed differential pressure drops abruptly after a certain period of time has lapsed, the growth of the agglomerate X at this time can be inferred. Further, since the bed differential pressure becomes approximately "0", fluidity can be determined to be

poor, and consequently, an urgent stop is required. It can also be confirmed from these experimental results that poor fluidity of the bed F can be effectively suppressed in the case where the ferronickel slag is added.

[0040]

Moreover, in the combustion method for the CFB boiler 1 related to the present embodiment, the ferronickel slag is also added to the inside of the loop seal 9a of the circulation line 9. The flow force of the fluidized material Fa in the loop seal 9a is significantly weak compared to the flow force in the bed F formed in the combustion tower 3. Accordingly, poor fluidity can be effectively prevented by actively adding the ferronickel slag to the inside of the loop seal 9a. Moreover, since the ferronickel slag supplied to the inside of the loop seal 9a is also circulated in the combustion tower 3, the effect of preventing poor fluidity of the bed F is also obtained.

[0041]

The effects of the combustion method for the CFB boiler 1 described above will be described. In a case where alkali-containing biomass fuel is used as the fuel for the CFB boiler, a chemical reaction is caused between alkaline components, such as potassium (K) or sodium (Na), and quartz particles that are principal components of the fluidized material Fa, and alkali silicate are formed. This alkali

silicate, which is a low melting-point compound that melts at about 700°C, may form an adhesion layer Fa on the surface of particles serving as the fluidized material Fa, and may obstruct the fluidization of the fluidized material Fa.

[0042]

Accordingly, in order to allow for adaptation of alkali-containing biomass fuel in a related-art CFB boiler, it is necessary to keep the operating temperature low in order to suppress poor fluidity (generation of an agglomerate). Otherwise, in order to form the environment in the furnace where poor fluidity does not occur easily, processing, such as mixed combustion with coal, input of an additive, or replacement of a fluidized material, or complicated control management, is needed, whereby the CO_2 reduction effect may hardly be expected, the waste of additive resources or an increase in running costs may be brought about, and, further, a lot of waste (pulled-out waste fluidized material generated with the replacement exchange of the fluidized material) may be generated, which is not practical. Accordingly, in the case where alkali-containing biomass fuel is used as the fuel for the CFB boiler, it is very difficult to make improvement in energy recovery efficiency and prevention of poor fluidity compatible with each other.

[0043]

However, in the above combustion method for the CFB boiler 1,

the ferronickel slag is supplied to the combustion tower 3 of the CFB boiler 1 in addition to the alkali-containing biomass fuel, and magnesium oxide is contained in the ferronickel slag. Therefore, generation of alkali silicate can be suppressed. Accordingly, a possibility that poor fluidity may occur in conjunction with generation of low-melting-point compounds decreases and the operation of the CFB boiler 1 at high temperatures is possible. As a result, improvement in energy recovery efficiency and prevention of poor fluidity can be made easily compatible.

[0044]

Moreover, in the related art, the ferronickel slag has only an application of being used as pavement, and is normally disposed of. However, according to the present embodiment, it is advantageous also from a viewpoint that this ferronickel slag is effectively used. Moreover, since magnesium carbonate or magnesium hydroxide is not contained but magnesium oxide is contained in the ferronickel slag, the magnesium oxide contributes directly to suppression of generation of alkali silicate. Thus, high energy recovery efficiency can be expected compared to the case where magnesium carbonate or magnesium hydroxide is added.

[0045]

Although the invention has been specifically described on the

basis of its preferred embodiment, the invention is not limited to the above embodiment. For example, in the above embodiment, the ferronickel slag is illustrated as the refining slag. However, it is also possible to use other refining slags produced by refining of an ore.

[0046]

Additionally, it is also possible to use a refining slag for mixed use with or as an alternative to a fluidized material of a fluidized bed boiler that uses the low-quality fluidized material that contains alkaline components. In this case, since a fluidized bed using the refining slag can be formed, poor fluidity of the fluidized bed can be effectively suppressed without any bias.

Moreover, the effects of removing strong fouling and depository adhesion to a boiler steam superheater heat transfer tube, and the effect of suppressing corrosion of a boiler steam superheater heat transfer surface tube can be expected.

Reference Signs List

[0047]

1: CFB BOILER (FLUIDIZED BED BOILER)

3: COMBUSTION TOWER (FURNACE BODY)

9a: LOOP SEAL (CIRCULATION SEAL SECTION)

F: BED (FLUIDIZED BED)

Fa: FLUIDIZED MATERIAL

G: EXHAUST GAS

CLAIMS

1. A combustion method for a fluidized bed boiler using fuel containing alkaline components, the method comprising:

adding a refining slag produced by refining of an ore in addition to the fuel, and burning the fuel in the fluidized bed boiler.

2. The combustion method for a fluidized bed boiler according to Claim 1, wherein the refining slag is used as a fluidized material of the fluidized bed boiler.

3. The combustion method for a fluidized bed boiler according to Claim 1 or 2, wherein the fluidized bed boiler includes

a furnace body;

a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas; and

a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing back flow from the furnace body, and wherein the refining slag is supplied to the circulation seal section.

4. A fluidized bed boiler using fuel containing alkaline components,

the fluidized bed boiler comprising:

a furnace body that burns fuel to which a refining slag produced by the refining of an ore is added.

5. The fluidized bed boiler according to Claim 4, wherein the refining slag is put into the furnace body as a fluidized material.

6. The fluidized bed boiler according to Claim 4 or 5, further comprising:

a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas;

a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing back flow from the furnace body, and

wherein the refining slag is supplied to the circulation seal section.

[0006]

The invention aims to solve the above problems, and to provide a combustion method for a fluidized bed boiler, and a fluidized bed boiler that can improve energy recovery efficiency while preventing poor fluidity, even in a case where fuel containing alkaline components is used.

Solution to Problem

[0007]

The present inventor focused on the ferronickel slag that is a kind of refining slag, containing about 30% (wt.% concentration) of magnesium oxide, and intensively studied effective use of the refining slag. As a result, the inventor obtained the knowledge that, if the ferronickel slag is added to a fluidized bed boiler, poor fluidity can be effectively prevented, and have derived the invention.

[0008]

That is, the invention provides a combustion method for a fluidized bed boiler using fuel containing alkaline components, the method including adding a refining slag produced by refining of an ore as a fluidized material of the fluidized bed boiler, and burning the fuel while forming a coating with a high melting point on a surface of the refining slag by reacting the refining slag with the alkaline components in the fuel during fluidization.

[0009]

In a case where fuel containing alkaline components, such as biomass fuel, is used as the fuel for the fluidized bed boiler, alkali silicate is formed by a chemical reaction between alkaline components, such as potassium (K) or sodium (Na), and quartz particles serving as fluidized material components. This alkali silicate, which is a low melting-point compound that melts at about 700°C, may form an adhesion layer on the surface of particles serving as the fluidized material, and may obstruct the fluidization of the fluidized material. However, in the invention, the refining slag is supplied to the fluidized bed boiler in addition to the fuel containing alkaline components, and magnesium oxide is contained in the refining slag. Therefore, generation of alkali silicate can be suppressed. Accordingly, a possibility that poor fluidity may occur in conjunction with generation of low-melting-point compounds decreases and the operation of the fluidized bed boiler at high temperatures is possible. As a result, it becomes easier to improve energy recovery efficiency. Moreover, since magnesium carbonate or magnesium hydroxide is not contained but magnesium oxide is contained in the refining slag, the magnesium oxide contributes directly to suppression of generation of alkali silicate. Thus, high energy recovery efficiency can be expected compared to the case where magnesium carbonate or magnesium hydroxide is added. Moreover, since a refining slag produced by refining of an ore is added as the fluidized material of the fluidized

bed boiler, a fluidized bed can be formed using the refining slag and poor fluidity of the fluidized bed can be effectively suppressed without any bias.

[0010]

Moreover, the fluidized bed boiler may include a furnace body, supply the refining slag to a fluidized material separated from an exhaust gas exhausted from the furnace body, and independently of supply of the fuel, return the fluidized material to which the refining slag is supplied to the furnace body.

[0011]

Moreover, preferably, the fluidized bed boiler includes a furnace body, a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas, a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing a back flow from the furnace body, and the refining slag is supplied to the circulation seal section. Poor fluidity in the circulation seal section can be effectively deterred.

[0012]

Additionally, the invention provides a fluidized bed boiler using fuel containing alkaline components, the fluidized bed boiler

including a furnace body that burns fuel, a refining slag produced by refining of an ore being added to the furnace body and the fuel being burned while forming a coating with a high melting point on a surface of the refining slag by reacting the refining slag with the alkaline components in the fuel during fluidization. According to the invention, even in a case where fuel containing alkaline components is used, improvement in energy recovery efficiency and prevention of poor fluidity can be made compatible. Moreover, since a refining slag produced by refining of an ore is added as the fluidized material, a fluidized bed can be formed using the refining slag and poor fluidity of the fluidized bed can be effectively suppressed without any bias.

[0013]

Moreover, a refining slag may be supplied to the fluidized material separated from an exhaust gas exhausted from the furnace body and, independently of supply of the fuel, the fluidized material to which the refining slag is supplied may be returned to the furnace body.

[0014]

Moreover, preferably, the fluidized bed boiler further includes a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas, and a circulation seal section that returns the fluidized material separated

in the separation section to the inside of the furnace body while preventing a back flow from the furnace body, and the refining slag is supplied to the circulation seal section. According to this configuration, poor fluidity in the circulation seal section can be effectively deterred.

[Advantageous Effects of Invention]

[0015]

According to the invention, in a case where fuel containing alkaline components is used as the fuel for the fluidized bed boiler, improvement in energy recovery efficiency and prevention of poor fluidity can be made compatible.

[Brief Description of Drawings]

[0016]

FIG. 1 is an explanatory view schematically showing a fluidized bed boiler.

FIGS. 2A and 2B are explanatory views showing a generation mechanism of agglomerate; FIG. 2A is a view illustrating a coating inducing mechanism, and FIG. 2B is a view illustrating a melting inducing mechanism.

FIG. 3 is a K_2O–SiO_2 phase diagram.

FIG. 4 is an MgO–SiO_2 phase diagram.

FIG. 5 is an MgO–K_2O–SiO_2 phase diagram.

FIG. 6 is an explanatory view schematically showing a phase where MgO acts on eutectic coating C.

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FIG. 8 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where a ferronickel slag is added.

FIG. 9 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where a ferronickel slag is not added (no addition).

[Description of Embodiments]

[0017]

A preferred embodiment of a fluidized bed boiler and a combustion method for a fluidized bed boiler related to the invention will be described below, referring to the drawings.

[0018]

As shown in FIG. 1, the fluidized bed boiler (hereinafter referred to as "a CFB boiler") 1 includes a combustion tower (furnace body) 3 that burns fuel to heat the water in an airtight container to generate steam, a cyclone separator (separation section) 5 that separates solids from combustion gas (hereinafter referred to as "exhaust gas") G produced in the combustion tower 3, a heat recovery

section 7 that recovers the heat of the exhaust gas G, a circulation line 9 through which fly ash separated from the exhaust gas G in the cyclone separator 5, i.e., a fluidized material Fa (refer to FIG. 2) separated from the exhaust gas G, is returned to a lower part of the combustion tower 3, and the like. In addition, a heat exchange tube, such as a superheater, is arranged in the heat recovery section 7.

[0019]

Biomass fuel, such as rice husk or EFB (Empty Fruit Bunches), is put into the combustion tower 3. This kind of biomass fuel is low-grade fuel containing a number of alkaline components, such as potassium or sodium. Moreover, a ferronickel slag that is a kind of refining slag is put into the combustion tower 3. The fluidized material Fa composed mainly of quartz particles is put into the combustion tower 3, air is supplied into the fluidized material Fa from a lower part of the combustion tower, and the fluidized material Fa is fluidized to form a fluidized bed (hereinafter referred to as a "bed") F. Combustion of fuel is promoted through the formation of the bed F. The exhaust gas G produced as a result of the combustion goes up within the combustion tower 3 while accompanying a portion of the fluidized material Fa. In addition, although an aspect in which the ferronickel slag is added into the fluidized material Fa has been described in the present embodiment, it is also possible to use the ferronickel slag itself as the fluidized material Fa.

[0020]

The cyclone separator 5 is arranged adjacent to the combustion tower 3, receives the exhaust gas G exhausted from the combustion tower 3 and the fluidized material Fa accompanied by the exhaust gas G, and separates the exhaust gas G and the fluidized material Fa due to a centrifugation action to return the fluidized material Fa to the combustion tower 3, and send the exhaust gas G into the heat recovery section 7.

[0021]

The circulation line 9 is connected to the cyclone separator 5. The circulation line 9 consists of a line connected to the lower part of the combustion tower 3, and a loop seal (circulation seal section) 9a is provided on the circulation line 9. The loop seal 9a is a facility that prevents back flow of the exhaust gas G from the combustion tower 3, and the fluidized material Fa sent in from the cyclone separator 5 is accumulated in the loop seal 9a, and the fluidized material Fa is put into the combustion tower 3 from a return chute section 9b at an outlet of the loop seal 9a.

[0022]

Additionally, the CFB boiler 1 includes a refining slag supply section 11 for supplying the ferronickel slag that is a kind of refining slag into the loop seal 9a. By supplying the ferronickel slag into

the loop seal 9a, poor fluidity within the loop seal 9a can be effectively suppressed.

[0023]

Next, a phenomenon that occurs when biomass fuel is put into the CFB boiler 1 and is burned will be described.

[0024]

The concept of generation of bottom ash and fly ash in the combustion of the biomass fuel will be described. The bottom ash is formed as particles as components in the biomass fuel condense, melt, agglomerate, and adhere with sand that is the fluidized material Fa acting as a seed, or react chemically on the sand surface. Additionally, the fly ash is formed by the condensation, melting, and agglomeration of the components in the biomass fuel itself if fine components are removed from some of the bottom ash that is formed as particles.

[0025]

A major cause of fluidization impediment in the fluidized material (also referred to as "fluidized sand" or "bed material") Fa in the combustion of the biomass fuel is an agglomerate X (refer to FIG. 2). It is considered that that most of the agglomerate X is produced as the melt (the melt of substance formed by the components in the biomass fuel) of low melting-point compounds adheres to the

surface of the fluidized material Fa, or is eutectically formed on the surface of the fluidized material Fa (the components in the biomass fuel chemically react on the surface of the fluidized material Fa), and is generated due to two mechanisms known as melting inducement and coating inducement.

[0026]

Specifically, the major cause of generation of the agglomerate X when the biomass fuel is burned is specified to be due to the fact that a chemical reaction is caused between the alkaline components from the biomass fuel, for example, potassium, (K), sodium (Na), or the like and quartz particles that are principal components of the fluidized material Fa, and an adhesive alkali silicate layer is formed on the surface of the fluidized material Fa. In addition, in addition to the alkaline components, it is confirmed that phosphor is also an important factor in the agglomerate X.

[0027]

(Melting Inducing Mechanism)

As shown in FIG. 2B, the agglomerate X of the melting inducing mechanism is produced as bottom ash particle groups, in which the melt M of the low melting-point compounds (alkali silicate) has adhered to the surface of the fluidized material Fa, gather together. The control factors of this mechanism are local temperature and fuel ash

composition. In the combustion ash containing high-concentration alkaline components and chlorine, the agglomerate X tends to be formed through the melting inducing mechanism.

[0028]

(Coating Inducing Mechanism)

As shown in FIG. 2A, as for the agglomerate X of the coating inducing mechanism, the bottom ash particle groups, in which eutectic coating (alkali silicate phase) C on the surface of the fluidized material Fa is formed, are repeatedly joined and separated by the eutectic coating C thereof. As a result, particle agglomeration is started, which results in the formation of the agglomerate X that gradually becomes a neck (fluidization obstruction factor). The major control factors of this mechanism are eutectic coating thickness (ease of joining and separation), eutectic coating composition (joining strength), and local temperature.

[0029]

In addition, it has been confirmed from the detailed analysis results of a portion that is actually the coated surface of the fluidized material Fa that this coating layer is eutectic coating (K_2O-SiO_2: alkali silicate layer) C. As shown in FIG. 3, this eutectic coating C begins to melt at 700°C. It can be confirmed that particles that are the fluidized material Fa are caused to easily adhere and

agglomerate to each other at a temperature in the fluidized material Fa of the CFB boiler 1, specifically, at 800°C to 900°C. In addition, FIG. 3 is a K_2O–SiO_2 phase diagram.

[0030]

Next, the relationship between the formation of the agglomerate X and magnesium oxide (MgO) will be described with reference to FIGS. 4 and 5. FIG. 4 is an MgO–SiO_2 phase diagram, and FIG. 5 is an MgO–K_2O–SiO_2 phase diagram. In addition, as shown in FIG. 3, a straight line La of FIG. 5 shows the process in which MgO is obtained from the phase of K_2O–$4SiO_2$, and an arrow Da shows a direction in which the ratio of MgO increases.

[0031]

A foremost reaction phase (a first reaction phase), as shown in FIG. 3, is produced at a low temperature of about 700°C. In this first reaction, coating or the like is formed in the form of K_2O–$4SiO_2$ (refer to FIG. 3). Next, in a second reaction phase, a reaction proceeds in the direction of an arrow Da of FIG. 5, and MgO reacts little by little with K_2O–$4SiO_2$ formed in the first reaction phase. If the phase where the reaction of MgO has proceeded is seen on the straight line La (refer to FIG. 5), a first point Pb where the ratio of MgO is several percent (about 4 %) and the melting temperature is 742°C is reached, whereby the melting point is raised (a third reaction phase). Next, a second

point Pa where the ratio of MgO is about 8 % and the melting temperature is 1000°C is reached, whereby the melting point is raised, and a layer with little adhesion is formed (a fourth reaction phase).

[0032]

MgO does not easily react above the second point Pa. This is because the melting point becomes 1000°C or higher and solids are produced, so a reaction with MgO (solids) is not easily caused. Here, if K_2O adheres again, for example, the phase returns to the first point Pb from the second point Pa, and 742°C becomes the melting point where adhesion becomes apt to occur. Next, the phase returns to the second reaction phase where MgO reacts, and the third reaction phase and the fourth reaction phase are repeated again.

[0033]

As shown in FIG. 4, in the reaction of MgO and SiO_2, it is easily inferred that melt is not formed up to 1543°C. Additionally, as shown in FIG. 5, even in the reaction of MgO and K_2O–SiO_2, it is inferred that melt is formed up to about 1000°C. Accordingly, when biomass fuel containing a lot of alkaline components is burned, formation of eutectic coating (K_2O–SiO_2: alkali silicate phase) C with a low melting point can be suppressed by adding magnesium oxide into the fluidized material Fa.

[0034]

Here, suppressing the formation of the eutectic coating C with a low melting point will be structurally described with reference to FIG. 6. FIG. 6 is an explanatory view schematically showing a phase where MgO acts on the eutectic coating C. If the eutectic coating C is formed on the surface of the fluidized material Fa as shown in FIG. 6, an $MgO-K_2O-SiO_2$ layer S with a high melting point is formed and solidified on the surface, and the melting point is raised. Additionally, even if the eutectic coating C is formed on the surface of the layer, the $MgO-K_2O-SiO_2$ layer S with a high melting point is formed and solidified, and the melting point is raised. As a result, even if the eutectic coating C with a low melting point is formed, the $MgO-K_2O-SiO_2$ layer S with a high melting point is formed on the surface of the eutectic coating C, and the melting point is kept from being lowered.

[0035]

Next, the refining slag, such as a ferronickel slag, will be described. The refining slag is a slag that is produced, for example, when refining a ferroalloy raw ore to generate ferroalloy. As a refining method, various methods, such as an electric furnace method or a thermite process can be applied. For example, in the electric furnace method, refining treatment in an electric furnace is performed after pretreatment of the raw ore, and the residue that remains after

a desired metal is extracted in the refining treatment becomes a refining slag. In the present embodiment, a ferronickel slag is illustrated as the refining slag.

[0036]

FIG. 7 is a view illustrating the properties of three samples that are ferronickel slags. For example, magnesium oxide (MgO) with 28.1% wt.% concentration is contained in Sample A, 35.5% of magnesium oxide (MgO) is contained in Sample B, and about 50.0% to 55% of magnesium oxide (MgO) is contained in Sample C. As such, at least 30% or more of magnesium oxide is contained in the ferronickel slag. Accordingly, it is inferred that the ferronickel slag is supplied into the combustion tower 3 of the CFB boiler 1, so that the formation of the agglomerate X can be suppressed, and poor fluidity can be effectively suppressed.

[0037]

Next, the combustion method for the CFB boiler 1 in a case where low-grade biomass fuel is used as boiler fuel will be described. The fluidized material Fa that forms the bed F has already been put into the combustion tower 3 of the CFB boiler 1. A ferronickel slag is supplied into the combustion tower 3 in addition to the biomass fuel, and combustion is caused by a burner (not shown) while air is supplied from the lower part of the fluidized material Fa to form the bed F. By adding the ferronickel slag into the fluidized material Fa in the

combustion tower 3, magnesium oxide in the ferronickel slag can contribute to suppression of the formation of the agglomerate X and effective suppression of poor fluidity of the bed F.

[0038]

Here, the effects in a case where the ferronickel slag is added will be described with reference to FIGS. 8 and 9, as compared to a case where the ferronickel slag is not added. In addition, FIG. 8 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where the ferronickel slag is added, and FIG. 9 is a graph showing the relationship between operating time, bed temperature, and bed differential pressure, in a case where the ferronickel slag is not added (no addition). In addition, the bed differential pressure shows pressure differential at upper and lower positions in the bed F that is being fluidized, and if poor fluidity occurs, the bed differential pressure drops abruptly and becomes "0" ultimately. Additionally, in the experimental conditions shown in FIGS. 8 and 9, the concentration of potassium contained in the bed F in the case where the ferronickel slag is not added is 0.6 wt% (ash base), whereas the concentration of potassium (K) contained in the bed F is as high as 2.6 wt% (ash base) in the case where the ferronickel slag is not added. Accordingly, the case where the ferronickel slag is not added becomes the environment in which the agglomerate X is easily formed.

[0039]

As shown in FIG. 8, in the case where the ferronickel slag is added, even if the bed temperature exceeds 800°C, it can be determined that there is no great change in the bed differential pressure and fluidity is good. On the other hand, as shown in FIG. 9, in the case where the ferronickel slag is not added, since the bed temperature exceeds 800°C, and the bed differential pressure drops abruptly after a certain period of time has lapsed, the growth of the agglomerate X at this time can be inferred. Further, since the bed differential pressure becomes approximately "0", fluidity can be determined to be poor, and consequently, an urgent stop is required. It can also be confirmed from these experimental results that poor fluidity of the bed F can be effectively suppressed in the case where the ferronickel slag is added.

[0040]

Moreover, in the combustion method for the CFB boiler 1 related to the present embodiment, the ferronickel slag is also added to the inside of the loop seal 9a of the circulation line 9. The flow force of the fluidized material Fa in the loop seal 9a is significantly weak compared to the flow force in the bed F formed in the combustion tower 3. Accordingly, poor fluidity can be effectively prevented by actively adding the ferronickel slag to the inside of the loop seal 9a. Moreover, since the ferronickel slag supplied to the inside of

the loop seal 9a is also circulated in the combustion tower 3, the effect of preventing poor fluidity of the bed F is also obtained.

[0041]

The effects of the combustion method for the CFB boiler 1 described above will be described. In a case where alkali-containing biomass fuel is used as the fuel for the CFB boiler, a chemical reaction is caused between alkaline components, such as potassium (K) or sodium (Na), and quartz particles that are principal components of the fluidized material Fa, and alkali silicate are formed. This alkali silicate, which is a low melting-point compound that melts at about 700°C, may form an adhesion layer Fa on the surface of particles serving as the fluidized material Fa, and may obstruct the fluidization of the fluidized material Fa.

[0042]

Accordingly, in order to allow for adaptation of alkali-containing biomass fuel in a related-art CFB boiler, it is necessary to keep the operating temperature low in order to suppress poor fluidity (generation of an agglomerate). Otherwise, in order to form the environment in the furnace where poor fluidity does not occur easily, processing, such as mixed combustion with coal, input of an additive, or replacement of a fluidized material, or complicated control management, is needed, whereby the CO_2 reduction effect may

hardly be expected, the waste of additive resources or an increase in running costs may be brought about, and, further, a lot of waste (pulled-out waste fluidized material generated with the replacement exchange of the fluidized material) may be generated, which is not practical. Accordingly, in the case where alkali-containing biomass fuel is used as the fuel for the CFB boiler, it is very difficult to make improvement in energy recovery efficiency and prevention of poor fluidity compatible with each other.

[0043]

However, in the above combustion method for the CFB boiler 1, the ferronickel slag is supplied to the combustion tower 3 of the CFB boiler 1 in addition to the alkali-containing biomass fuel, and magnesium oxide is contained in the ferronickel slag. Therefore, generation of alkali silicate can be suppressed. Accordingly, a possibility that poor fluidity may occur in conjunction with generation of low-melting-point compounds decreases and the operation of the CFB boiler 1 at high temperatures is possible. As a result, improvement in energy recovery efficiency and prevention of poor fluidity can be made easily compatible.

[0044]

Moreover, since magnesium carbonate or magnesium hydroxide is not contained but magnesium oxide is contained in the ferronickel slag,

the magnesium oxide contributes directly to suppression of generation of alkali silicate. Thus, high energy recovery efficiency can be expected compared to the case where magnesium carbonate or magnesium hydroxide is added.

[0045]

Although the invention has been specifically described on the basis of its preferred embodiment, the invention is not limited to the above embodiment. For example, in the above embodiment, the ferronickel slag is illustrated as the refining slag. However, it is also possible to use other refining slags produced by refining of an ore.

[0046]

Additionally, it is also possible to use a refining slag for mixed use with or as an alternative to a fluidized material of a fluidized bed boiler that uses the low-quality fluidized material that contains alkaline components. In this case, since a fluidized bed using the refining slag can be formed, poor fluidity of the fluidized bed can be effectively suppressed without any bias.

Moreover, the effects of removing strong fouling and depository adhesion to a boiler steam superheater heat transfer tube, and the effect of suppressing corrosion of a boiler steam superheater heat transfer surface tube can be expected.

[Reference Signs List]

[0047]

1: CFB BOILER (FLUIDIZED BED BOILER)

3: COMBUSTION TOWER (FURNACE BODY)

9a: LOOP SEAL (CIRCULATION SEAL SECTION)

F: BED (FLUIDIZED BED)

Fa: FLUIDIZED MATERIAL

G: EXHAUST GAS

CLAIMS

1. A combustion method for a fluidized bed boiler using fuel containing alkaline components, the method comprising:

adding a refining slag produced by refining of an ore as a fluidized material of the fluidized bed boiler, and burning the fuel while forming a coating with a high melting point on a surface of the refining slag by reacting the refining slag with the alkaline components in the fuel during fluidization.

2. The combustion method for a fluidized bed boiler according to Claim 1,

wherein the fluidized bed boiler includes a furnace body, and supplies the refining slag to the fluidized material separated from an exhaust gas exhausted from the furnace body and, independently of supply of the fuel, returns the fluidized material to which the refining slag is supplied to the furnace body.

3. The combustion method for a fluidized bed boiler according to Claim 1 or 2,

wherein the fluidized bed boiler includes

a furnace body;

a separation section that separates a fluidized material

in an exhaust gas exhausted from the furnace body from the exhaust gas; and

a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing back flow from the furnace body, and

wherein the refining slag is supplied to the circulation seal section.

4. A fluidized bed boiler using fuel containing alkaline components, the fluidized bed boiler comprising:

a furnace body that burns the fuel,

wherein a refining slag produced by refining of an ore is put into the furnace body as a fluidized material, and the fuel is burned while a coating with a high melting point is formed on a surface of the refining slag by reacting the refining slug with the alkaline components in the fuel during fluidization.

5. The fluidized bed boiler according to Claim 4,

wherein the refining slag is supplied to the fluidized material separated from an exhaust gas exhausted from the furnace body and, independently of supply of the fuel, the fluidized material to which the refining slag is supplied is returned to the furnace body.

6. The fluidized bed boiler according to Claim 4 or 5, further comprising:

a separation section that separates a fluidized material in an exhaust gas exhausted from the furnace body from the exhaust gas;

a circulation seal section that returns the fluidized material separated in the separation section to the inside of the furnace body while preventing back flow from the furnace body, and

wherein the refining slag is supplied to the circulation seal section.