



US 20120174836A1

(19) **United States**(12) **Patent Application Publication**
Akiyama et al.(10) **Pub. No.: US 2012/0174836 A1**(43) **Pub. Date: Jul. 12, 2012**(54) **METHOD FOR REDUCING ADHESION OF
ASH IN BOILER AND DEVICE FOR THE
SAME****Publication Classification**(51) **Int. Cl.****F23C 1/00** (2006.01)**F23N 5/00** (2006.01)**F23K 1/00** (2006.01)(52) **U.S. Cl. 110/342; 110/327; 110/186**(75) Inventors: **Katsuya Akiyama**, Kobe-shi (JP);
Haeyang Pak, Kobe-shi (JP)(73) Assignee: **Kabushiki Kaisha Kobe Seike Sho**
(Kobe Steel, Ltd.), Kobe-shi,
Hyogo (JP)(21) Appl. No.: **13/395,332**(22) PCT Filed: **Oct. 5, 2010**(86) PCT No.: **PCT/JP2010/067484**

§ 371 (c)(1),

(2), (4) Date: **Mar. 9, 2012**(30) **Foreign Application Priority Data**

Oct. 9, 2009 (JP) 2009-234852

(57) **ABSTRACT**

A device for reducing ash adhesion in a boiler, includes: a calculator (9) which, in the case of mixing one or more types of solid fuels, calculates and determines the mixing ratio of the solid fuels so that the resultant solid fuel mixture has a slag viscosity not lower than a reference value at a predetermined atmospheric temperature; and fuel supply amount regulators (3a, 3b) which regulate the amount of the solid fuels to be supplied to the boiler based on the mixing ratio as described above. By using this device, ash adhesion in a boiler can be easily and accurately predicted and, therefore, ash adhesion can be reduced even in the case of using various types of solid fuels including a low-grade coal as fuel.

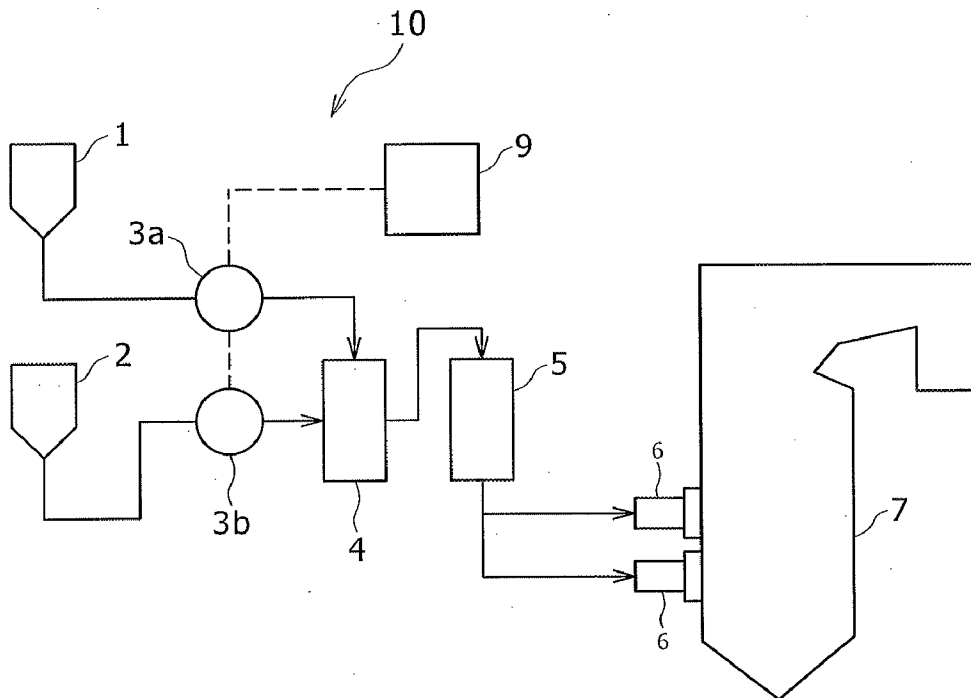


FIG. 1

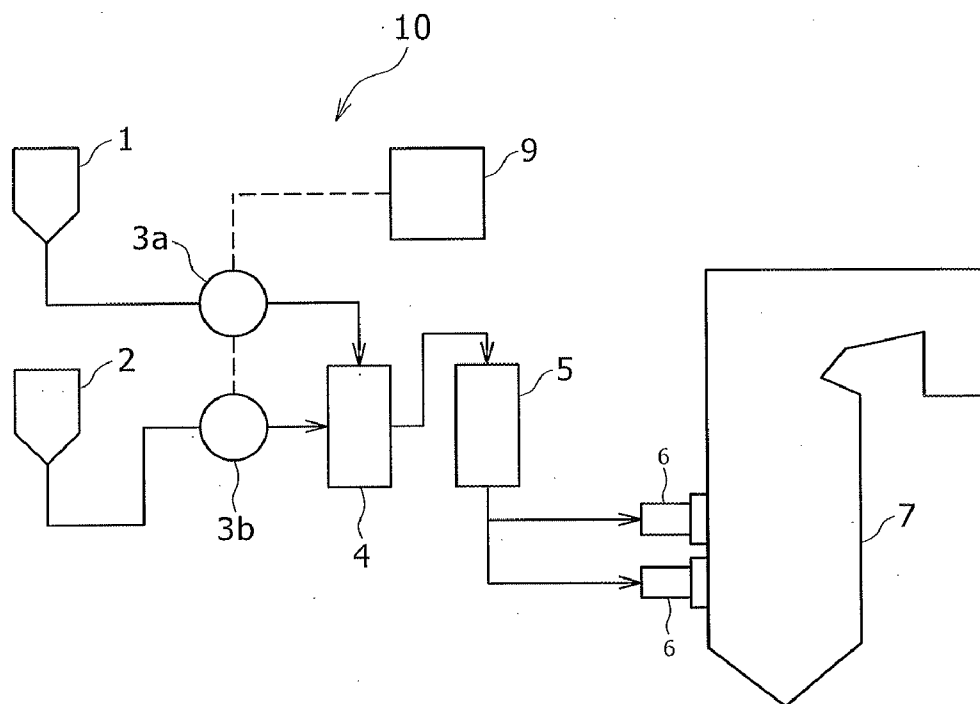


FIG. 2

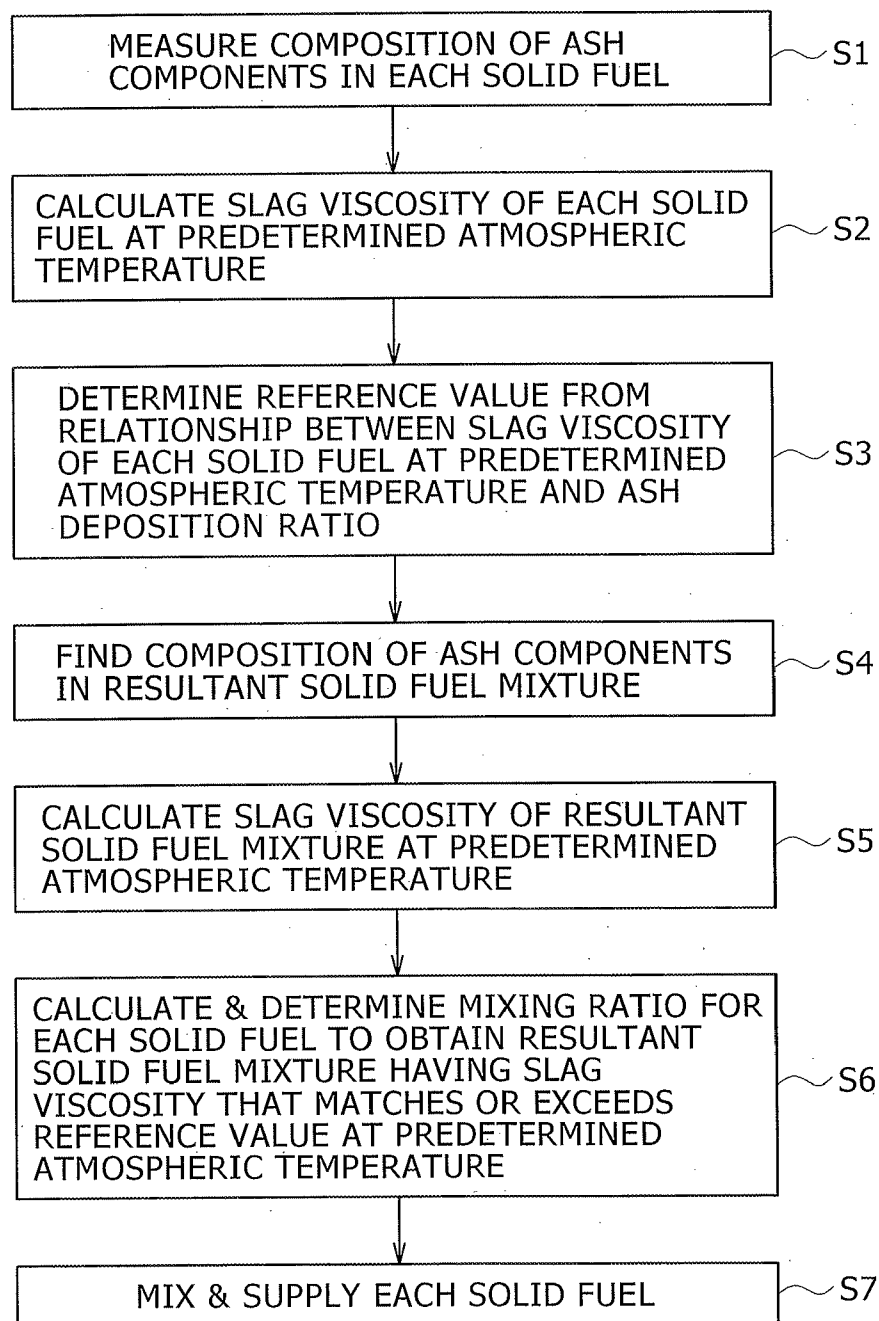
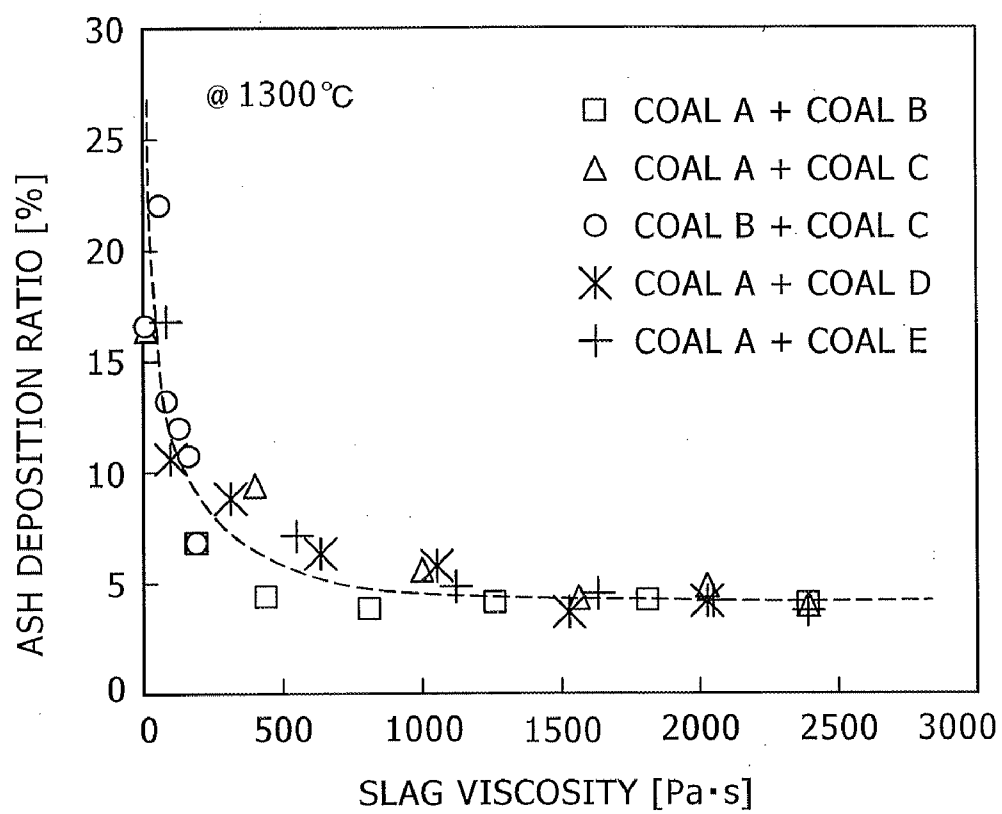


FIG. 3



METHOD FOR REDUCING ADHESION OF ASH IN BOILER AND DEVICE FOR THE SAME

TECHNICAL FIELD

[0001] The present invention relates to a method for reducing adhesion of ash and a device for reducing adhesion of ash in a boiler which uses, as fuel, a solid fuel.

BACKGROUND ART

[0002] In conventional boilers using a solid fuel as fuel, pulverized coal obtained by crushing the solid fuel in a crusher is supplied as fuel along with carrier air to the boilers. Such a boiler includes a furnace for burning the supplied fuel by means of a burner or the like to generate heat, and a set of heat exchanger tubes arranged from an upper part to a downstream part of the furnace to cause heat exchange with a combustion gas directed to flow therein. The combustion gas generated in the boiler is discharged from a chimney. Here, the set of heat exchanger tubes is composed of an upper heat transfer unit in which a secondary heater, a tertiary heater, a final heater and a secondary reheater are arranged side by side at predetermined intervals in an upper part of the furnace, and a rear heat transfer unit in which a primary heater, a primary reheater and a coal economizer are arranged in a rear part of the furnace.

[0003] In the boiler as described above, ash generated from burned coal is caused to flow with combustion gas of the boiler. The flowing ash adheres, in the course of discharge of the combustion gas, to wall surfaces of the furnace or the set of heat exchanger tubes, and deposits thereon, resulting in occurrence of slagging or fouling. When the slagging or fouling occurs, heat transfer surfaces of the heat exchanger tubes are covered, thereby significantly reducing heat absorption efficiency. Further, when a huge clinker produced on the wall surface or other parts by the slagging or fouling falls down, problems may arise, including drastic pressure change in the furnace, a damage to the heat exchanger tubes disposed on a furnace bottom, and blockage of the furnace bottom.

[0004] On the other hand, because the elements of the upper heat transfer unit provided in the upper part of the furnace are arranged at narrow intervals, the ash that adheres to anywhere in the upper heat transfer unit may cause significant changes in furnace pressure. In addition, when the ash adhering to the heat exchanger tubes grows therebetween to an extent that a gas flow path is clogged with the ash, it becomes impossible for the combustion gas to flow through the set of heat exchanger tubes, which could cause an operational failure.

[0005] Further, in a region close to the burner, because the temperature in the vicinity of the wall surfaces of the furnace is elevated by radiation heat from combustion flames of fuel, the ash tends to easily adhere and melt onto the set of heat exchanger tubes having relatively low temperatures, which produces a problem in that growth of a huge clinker is facilitated.

[0006] For stable operation of the boiler, it is necessary that a possibility of adhesion of ash to the wall surfaces of the furnace or the set of heat exchanger tubes resulting from combustion of the solid fuel should be predicted in advance, to thereby prevent problems associated with the adhesion of ash from occurring. To this end, it is being attempted to indicate the possibility of adhesion of ash as an index.

[0007] In Non-patent Literature 1, for example, a method is used in which the possibility of adhesion of ash is previously predicted in accordance with both evaluation criteria and indices which are related to ash based on ash composition representing ash containing elements in the form of oxides. However, the indices and the evaluation criteria shown in Non-patent Literature 1 are defined for bituminous coal of a high-grade coal which is less problematic in terms of the adhesion of ash, but does not cover low-grade coals (such as, for example, subbituminous coal, lignite coal, high-silica coal, or high-calcium coal) which are now in increasing demand. Therefore, there is a problem in that a relationship between the indices and adhesion of ash described in Non-patent Literature 1 does not necessarily tend to match an actual relationship.

[0008] With a view toward covering the low-grade coals, Patent Literature 1 discloses that coal ash which is obtained by previously incinerating coal to be used is sintered, and a degree of conglutination of the sintered ash is measured for predicting and evaluating adhesion of ash.

RELATED ART DOCUMENT

Patent Literature

[0009] [Patent literature 1] Japanese Patent Laid-Open Publication No. 2004-361368

[Non-Patent Literature]

[0010] [Non-Patent Literature 1] "Understanding slagging and fouling during pf combustion" (IEACR/72) written by Gordon Couch, 1994

SUMMARY OF INVENTION

Problem to be Solved by the Invention

[0011] It is, however, not possible to obtain sintering and melting properties of ash unless a measurement is carried out using actual ash. Further, because a great deal of time and effort is required to conduct the measurement under a plurality of coal blending conditions, the measurement has a drawback of lack of convenience and simplicity. Therefore, even according to a method for predicting and evaluating adhesion of coal ash disclosed in Patent Document 1, adhesion of ash in the boiler can not be predicted in a simple and convenient way.

[0012] The present invention is directed to provide a method for reducing adhesion of ash in a boiler and a device for the same, with which adhesion of ash in the boiler can be accurately predicted in a simple and convenient way, and accordingly reduced even when various types of solid fuels including a low-grade coal are used as fuel.

Means to Solve the Problems

[0013] A method for reducing adhesion of ash in a boiler according to the present invention includes determining, when one or more types of solid fuels are mixed, a mixing ratio of each solid fuel calculated so as to obtain a resultant solid fuel mixture having a slag viscosity that matches or exceeds a reference value at a predetermined atmospheric temperature, and supplying the solid fuels mixed based on the mixing ratio as fuel to the boiler.

[0014] The above-described configuration is devised focusing attention on slag which is a component melted through combustion in the boiler, suspended in combustion

air inside the boiler, and carried by a stream of the combustion air while adhering to a furnace wall or the set of heat exchanger tubes. According to the above configuration, when one or more types of solid fuels including a low-grade coal are mixed, the mixing ratio of the solid fuels is determined based on the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature. Here, the solid fuels include coals, sludge carbides, biomass fuels and the like. Further, since an amount of heat is important in the boiler, a supply amount of the solid fuel to be used as fuel is determined in such a manner that the amount of heat input into the boiler is maintained constant.

[0015] In general, a percentage of molten slag, which is melted ash, contained in the solid fuel becomes higher according as the temperature increases. In turn, the slag viscosity is decreased according as the percentage of molten slag becomes higher. The decreased slag viscosity effects an increase in adhesiveness (or caking property) of slag, and thus allows slag particles to easily adhere to each other or allows slag to easily adhere to walls of the boiler. Moreover, ash having a higher ash alkalinity ($=(\text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO} + \text{Na}_2\text{O} + \text{K}_2\text{O})/(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{TiO}_2)$) calculated from a composition of ash components in the solid fuel tends to have a lower slag viscosity.

[0016] Accordingly, when a solid fuel having a higher ash alkalinity is appropriately mixed with a solid fuel having a lower ash alkalinity, to thereby increase the slag viscosity of the resultant solid fuel mixture, slag particles do not easily adhere to each other, or slag does not easily adhere to the wall of the boiler. As a result, both adhesion of slag to the boiler and generation of the slag can be reduced.

[0017] As such, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature is defined as an evaluation index, and an ash adhesion property is evaluated based on the slag viscosity in this invention. Then, the mixing ratio of solid fuels is calculated in such a manner that the slag viscosity of the resultant solid fuel mixture becomes equal to or greater than the reference value at the predetermined atmospheric temperature, and the mixing ratio is determined. In this way, even when various types of solid fuels including the low-grade coal are used as fuel, adhesion of ash in the boiler can be accurately predicted in a simple and convenient way, and accordingly reduced.

[0018] Further, in the method for reducing adhesion of ash in a boiler of this invention, the slag viscosity may be calculated based on a composition of ash components in the resultant solid fuel mixture. According to this configuration, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature can be found without carrying out any experiment.

[0019] Still further, in the method for reducing adhesion of ash in a boiler of this invention, the slag viscosity may be calculated based on a result of measuring a slag viscosity of slag formed by heating ash of each solid fuel at the predetermined atmospheric temperature. According to the above configuration, it is possible to obtain the slag viscosity adapted to actual conditions of the boiler.

[0020] Furthermore, in the method for reducing adhesion of ash in a boiler of this invention, the reference value may be a value of the slag viscosity which is, with reference to a relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and ash deposition ratio, associated with the ash deposition ratio of a predetermined value or lower. According to the above-described

configuration, because the ash deposition ratio can be reduced to the predetermined value or lower by setting the slag viscosity of the resultant solid fuel mixture to the value equal to or greater than the reference value, it becomes difficult for ash to adhere in the boiler. As a result, deposition of ash can be reduced. Here, the ash deposition ratio is obtained by calculating a ratio of an amount of ash that becomes deposited on an ash adhesion probe inserted into the boiler relative to an amount of ash that impinges on the ash adhesion probe. Then, the amount of ash that impinges on the ash adhesion probe is a total amount of ash that impinges on a projected area of the ash adhesion probe, and calculated from the supply amount of the solid fuels, ash contents in the solid fuels, and a furnace shape of the boiler.

[0021] Moreover, in the method for reducing adhesion of ash in a boiler of the present invention, the reference value may lie between 300 and 1000 Pa·s which are values of the slag viscosity associated with the ash deposition ratio of 5~7% or lower. According to this configuration, because the ash deposition ratio of 5~7% or lower contributes to suppression in tendency of ash to adhere in the boiler, adhesion of ash can be favorably reduced.

[0022] Further, in the method for reducing adhesion of ash in a boiler of the present invention, the predetermined atmospheric temperature may be an atmospheric temperature in a region close to a burner for burning each solid fuel. According to the above configuration, the slag viscosity of slag in ash can be determined adequately for each part inside the boiler, which makes it possible to appropriately calculate the mixing ratio of one or more types of the solid fuels.

[0023] Still further, in the method for reducing adhesion of ash in a boiler of the present invention, the predetermined atmospheric temperature may be a highest atmospheric temperature allowed by boiler design. According to this configuration, the appropriate mixing ratio of the one or more types of solid fuels can be calculated irrelevant to a combustion temperature inside the furnace of the boiler.

[0024] On the other hand, a device for reducing adhesion of ash in a boiler according to the present invention includes a calculating means which determines, when one or more types of solid fuels are mixed, a mixing ratio of the solid fuels calculated so as to obtain a resultant solid fuel mixture having a slag viscosity that matches or exceeds a reference value at a predetermined atmospheric temperature, and a fuel supply amount regulating means which regulates an amount of each solid fuel supplied to the boiler based on the mixing ratio.

[0025] The above-described configuration is devised focusing attention on slag which is a component melted through combustion in the boiler, suspended in combustion air inside the boiler, and carried by a stream of the combustion air while adhering to a furnace wall or a set of heat exchanger tubes. According to the above configuration, when one or more types of solid fuels including a low-grade coal are mixed, the mixing ratio of the solid fuels is determined based on the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature. Here, the solid fuels include coals, sludge carbides, biomass fuels and the like. Further, in the boiler where an amount of heat is important, a supply amount of the solid fuel to be used as fuel is determined in such a manner that the amount of heat input into the boiler is maintained constant.

[0026] In general, a percentage of molten slag in which ash contained in the solid fuel is melted becomes higher according as the temperature increases. In turn, the slag viscosity is

decreased according as the percentage of molten slag becomes higher. The decreased slag viscosity effects an increase in adhesiveness (or caking property) of slag, and thus allows slag particles to easily adhere to each other or allows slag to easily adhere to walls of the boiler. Moreover, ash having a higher ash alkalinity ($= (\text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO} + \text{Na}_2\text{O} + \text{K}_2\text{O}) / (\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{TiO}_2)$) calculated from a composition of ash components in the solid fuel tends to have a lower slag viscosity.

[0027] Accordingly, when a solid fuel having a higher ash alkalinity is appropriately mixed with a solid fuel having a lower ash alkalinity, to thereby increase the slag viscosity of the resultant solid fuel mixture, slag particles do not easily adhere to each other, or slag does not easily adhere to the wall of the boiler. As a result, both adhesion of slag to the boiler and generation of the slag can be reduced.

[0028] As such, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature is defined as an evaluation index, and an ash adhesion property is evaluated based on the slag viscosity in this invention. Then, the mixing ratio of solid fuels is calculated in such a manner that the slag viscosity of the resultant solid fuel mixture becomes equal to or greater than the reference value at the predetermined atmospheric temperature, and the mixing ratio is determined. In this way, even when various types of solid fuels including the low-grade coal are used as fuel, adhesion of ash in the boiler can be accurately predicted in a simple and convenient way, and accordingly reduced.

[0029] Further, in the device for reducing adhesion of ash in a boiler of this invention, the slag viscosity may be calculated based on a composition of ash components in the resultant solid fuel mixture. According to this configuration, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature can be found without carrying out any experiment.

[0030] Still further, in the device for reducing adhesion of ash in a boiler of this invention, the slag viscosity may be calculated based on a result of measuring the slag viscosity of slag formed by heating ash of each solid fuel at the predetermined atmospheric temperature. According to the above configuration, it is possible to obtain the slag viscosity adapted to actual conditions of the boiler.

[0031] Furthermore, in the device for reducing adhesion of ash in a boiler of this invention, the reference value may be a value of the slag viscosity which is, with reference to the relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and an ash deposition ratio, associated with the Ash deposition ratio of the predetermined value or lower. According to the above-described configuration, because the ash deposition ratio can be reduced to the predetermined value or lower by setting the slag viscosity of the resultant solid fuel mixture to the value equal to or greater than the reference value, it becomes difficult for ash to adhere in the boiler. As a result, deposition of ash can be reduced. Here, the ash deposition ratio is obtained by calculating a ratio the amount of ash that becomes deposited on an ash adhesion probe inserted into the boiler relative to the amount of ash that impinges on the ash adhesion probe. Then, the amount of ash that impinges on the ash adhesion probe is the total amount of ash that impinges on the projected area of the ash adhesion probe, and calculated from the supply amount of the solid fuels, ash contents in the solid fuels, and the furnace shape of the boiler.

[0032] Moreover, in the device for reducing adhesion of ash in a boiler of the present invention, the reference value may lie between 300 and 1000 Pa·s which are values of the slag viscosity associated with the ash deposition ratio of 5~7% or lower. According to this configuration, because the ash deposition ratio becomes 5~7% or lower, leading to suppression in tendency of ash to adhere in the boiler, adhesion of ash can be favorably reduced.

[0033] Further, in the device for reducing adhesion of ash in a boiler of the present invention, the predetermined atmospheric temperature may be the atmospheric temperature in the region close to the burner for burning the solid fuels. According to the above configuration, the slag viscosity of slag in ash can be determined adequately for each part inside the boiler, which makes it possible to appropriately calculate the mixing ratio of one or more types of the solid fuels.

[0034] Still further, in the device for reducing adhesion of ash in a boiler of the present invention, the predetermined atmospheric temperature may be the highest atmospheric temperature allowed by boiler design. According to this configuration, the appropriate mixing ratio of the one or more types of solid fuels can be calculated irrelevant to the combustion temperature inside the furnace of the boiler.

Effects of the Invention

[0035] In the method for reducing adhesion of ash in a boiler and the device for the same, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature is taken as the evaluation index, and the ash adhesion property is evaluated based on the slag viscosity. Then, the mixing ratio of the solid fuels is calculated so as to obtain the resultant solid fuel mixture having a slag viscosity that matches or exceeds the reference value at the predetermined atmospheric temperature, and the mixing ratio is determined. As a result, even when various types of solid fuels including the low-grade coal are used as fuel, adhesion of ash in the boiler can be accurately predicted in a simple and convenient way, and accordingly reduced.

BRIEF DESCRIPTION OF DRAWINGS

[0036] FIG. 1 is a schematic diagram showing a device for reducing adhesion of ash in a boiler according to an embodiment of the present invention;

[0037] FIG. 2 is a step diagram showing process steps in a method for reducing adhesion of ash in a boiler according to an embodiment of this invention, and

[0038] FIG. 3 is a diagram showing a relationship between a slag viscosity and an ash deposition ratio at 1300° C.

EMBODIMENT FOR CARRYING OUT THE INVENTION

[0039] Hereinafter, a preferred embodiment of the present invention will be described with reference to the drawings.

<Configuration of Device for Reducing Adhesion of Ash in Boiler>

[0040] A device 10 for reducing adhesion of ash in a boiler according to an embodiment includes, as shown in FIG. 1, fuel supply amount regulators (fuel supply amount regulating means) 3a, 3b which regulate amounts of solid fuels supplied from hoppers 1, 2 to a boiler 7, and a calculator (calculating means) 9 which controls the fuel supply amount regulators 3a, 3b. The hoppers 1 and 2 respectively store solid fuels

whose ash properties are different from each other. Here, the solid fuels include coals, sludge carbides, biomass fuels and others.

[0041] A mixer **4**, a crusher **5**, and burners **6** are disposed between the hoppers **1**, **2** and the boiler **7**. The mixer **4** mixes two types of solid fuels, the supply amounts of which are regulated by the fuel supply amount regulators **3a**, **3b**. The crusher **5** crushes the solid fuels mixed through the mixer **4** into pulverized coal. The burner **6** initiates combustion using, as fuel, the pulverized coal supplied together with air from the crusher **5**. It should be noted that, although the two types of solid fuels are mixed in this embodiment, a configuration to mix one or more types of solid fuels may be employed.

[0042] The boiler **7** burns the pulverized coal and recovers heat therefrom. Note that the boiler **7** has a not-illustrated furnace for burning the pulverized coal supplied from the crusher **5** by means of the burners **6** or the like to generate heat, and a not-illustrated set of heat exchanger tubes which are arranged from an upper part to a downstream part of the furnace to cause heat exchange through a flow of a combustion gas therein. The combustion gas generated in the boiler **7** is directed to be discharged from a chimney. The set of the heat exchanger tubes is composed of an upper heat transfer unit including a secondary heater, a tertiary heater, a final heater, and a secondary reheater which are arranged side by side at predetermined intervals in the upper part of the furnace, and a rear heat transfer unit including a primary heater, a primary reheater, and a coal economizer which are arranged in a rear part of the furnace.

[0043] When the two types of solid fuels supplied from the hoppers **1**, **2** are mixed, the calculator **9** determines a mixing ratio of the two types of solid fuels based on a slag viscosity of a resultant solid fuel mixture at a predetermined atmospheric temperature. The predetermined atmospheric temperature will be described later. Here, the supply amount of the solid fuels to be used as fuel is determined so that an amount of heat to be input into the boiler **7** is maintained constant.

[0044] More specifically, coal properties, such as a water content, a calorific value, an ash content, a composition of ash components, of each solid fuel are previously collected and stored as data in the calculator **9**. Firstly, the calculator **9** calculates the slag viscosity of each solid fuel at the predetermined atmospheric temperature. The slag viscosity is calculated based on the previously measured composition of ash components in each solid fuel to be used in the boiler **7** using an equation which has been empirically obtained. Then, the calculator **9** associates the slag viscosity of each solid fuel at the predetermined atmospheric temperature with an ash deposition ratio.

[0045] Here, slag represents components which are melted through combustion of ash, suspended in combustion air inside the boiler **7**, and carried by a stream of the combustion air while adhering to walls of the furnace wall and/or the set of heat exchanger tubes. Further, the slag viscosity, which denotes a viscosity of slag at a certain temperature, is used as an evaluation index of an ash adhesion property in this embodiment.

[0046] Still further, the ash deposition ratio represents a degree of how easily ash adheres and becomes deposited. The ash deposition ratio is obtained by calculating a ratio of an amount of ash that becomes deposited on an ash adhesion probe inserted into the furnace of the boiler **7** relative to an amount of ash that impinges on the ash adhesion probe. The

amount of ash impinging on the ash adhesion probe is a total amount of ash impinging on a projected area of the ash adhesion probe. The amount of ash impinging on the ash adhesion probe can be obtained based on the supply amount of the solid fuel, the ash content in the solid fuel, and the furnace shape of the boiler **7**. It should be noted that calculation of the ash deposition ratio may be performed with respect to a combustion test furnace or an in-service boiler rather than the boiler **7**.

[0047] Next, the calculator **9** finds, based on a relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and the ash deposition ratio, a slag viscosity associated with an ash deposition ratio that matches or is lower than a predetermined value, and defines the found slag viscosity as a reference value. In this embodiment, the predetermined value of the ash deposition ratio is 5~7%, while the reference value is 300~1000 Pa-s which is the value of the slag viscosity capable of yielding the ash deposition ratio of 5~7% or lower.

[0048] Thereafter, using the mixing ratio of the two types of solid fuels as a parameter, the calculator **9** finds a composition of ash components in a resultant solid fuel mixture obtained when the two types of solid fuels are mixed. The composition of ash components is found based on the respective compositions of ash components in the solid fuels previously measured for each of the solid fuels.

[0049] Next, the calculator **9** calculates the slag viscosity of the resultant solid fuel mixture of the two types of solid fuels at the predetermined atmospheric temperature. The slag viscosity is calculated based on the composition of ash components in the resultant solid fuel mixture of the two types of solid fuels using the empirically determined equation. In this way, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature can be found without carrying out any experiment.

[0050] In this connection, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature may be calculated based on results of measurement which has been conducted in advance to measure the slag viscosity of slag formed by heating ash of each solid fuel at the predetermined atmospheric temperature. In this case, the slag viscosity adapted to actual conditions of the boiler **7** can be obtained.

[0051] Then, the calculator **9** calculates the mixing ratio of the two types of solid fuels so as to obtain the resultant solid fuel mixture having the slag viscosity that matches or exceeds the reference value at the predetermined atmospheric temperature. In this way, the mixing ratio of the two types of solid fuels is determined.

[0052] In this embodiment, focusing attention on slag as described above, when one or more types of solid fuels including a low-grade coal are mixed, the mixing ratio of the solid fuels is determined based on the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature.

[0053] In general, the percentage of molten slag, which is melted ash, contained in the solid fuel becomes high according as the temperature increases. In turn, the slag viscosity is decreased according as the percentage of the molten slag increases. The decreased slag viscosity effects an increase in adhesiveness (or caking property) of slag, and thus allows slag particles to easily adhere to each other or causes slag to easily adhere to walls of the boiler. Moreover, ash which has a higher ash alkalinity ($= (\text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO} + \text{Na}_2\text{O} + \text{K}_2\text{O}) /$

($\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{TiO}_2$) calculated from the composition of ash components in the solid fuel tends to have a lower slag viscosity.

[0054] Thus, a solid fuel having a higher ash alkalinity is appropriately mixed with a solid fuel having a lower ash alkalinity, to thereby increase the slag viscosity of the resultant solid fuel mixture. In this way, because it becomes difficult for the slag particles to adhere to each other or for the slag to adhere to the walls of the boiler, both adhesion of slag to the boiler 7 and generation of the slag can be suppressed.

[0055] The slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature is defined as the evaluation index, and the ash adhesion property is evaluated based on that slag viscosity. Then, the mixing ratio of the solid fuels is determined so as to obtain the resultant solid fuel mixture having the slag viscosity that matches or exceeds the reference value at the predetermined atmospheric temperature. In this way, even when various types of solid fuels including the low-grade coal are used as fuel, adhesion of ash in the boiler 7 can be accurately predicted in a simple and convenient way, and accordingly reduced.

[0056] With reference to the relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and the ash deposition ratio, the slag viscosity capable of yielding the ash deposition ratio of 5~7% or lower has a value of 300~1000 Pa·s, and this value is defined as the reference value. Therefore, when adjustment is performed such that the resultant solid fuel mixture has the slag viscosity of 300~1000 Pa·s or greater, the ash deposition ratio can be maintained at or below 5~7%, which makes the ash less prone to adhere in the boiler 7. As a result, adhesion of ash can be favorably reduced.

[0057] Here, in calculation of the slag viscosity, an atmospheric temperature in the vicinity of the burner 6 where adhesion of ash to the boiler walls notably occurs is used as the predetermined atmospheric temperature. The atmospheric temperature in the vicinity of the burner 6 is measured by a not-illustrated measurement instrument which is installed in the vicinity of the burner 6. However, the predetermined atmospheric temperature is not limited to the atmospheric temperature in the vicinity of the burner 6, but may be an atmospheric temperature in a desired part, such as the set of heat exchanger tubes where ash is likely to adhere, for example. In this way, because the slag viscosity of slag in ash can be appropriately determined for each part inside the boiler 7, it becomes possible to calculate a suitable mixing ratio of the two types of solid fuels.

[0058] On the other hand, in the calculation of the slag viscosity, a highest allowable atmospheric gas temperature in accordance with design specifications of the boiler 7 may be used as the predetermined atmospheric temperature. In this case, the suitable mixing ratio of the two types of solid fuels can be found irrespective of a combustion temperature in the furnace of the boiler 7.

<Operation of Device for Reducing Adhesion of Ash in Boiler>

[0059] Next, operation of the thus-configured device 10 for reducing adhesion of ash in a boiler, i.e. the method for reducing adhesion of ash in a boiler will be described.

[0060] As shown in FIG. 2, firstly, respective compositions of ash components in the two types of solid fuels which are to be used in the boiler 7 are measured (step S1). More specifically, coal properties, such as a water content, a calorific

value, an ash content, and a composition of ash components, of each solid fuel, are measured. Results of the measurement are collected and stored as data in the calculator 9. Next, the calculator 9 calculates, based on the respective compositions of ash components in the solid fuels measured in step S1, the slag viscosity of each solid fuel at the predetermined atmospheric temperature using the empirically determined equation (step 2).

[0061] Next, the calculator 9 finds, based on the relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and the ash deposition ratio, the slag viscosity associated with the ash deposition ratio that matches or is lower than a predetermined value, and defines the found slag viscosity as a reference value (step 3). In this embodiment, the predetermined value of the ash deposition ratio is 5~7%, while the reference value is 300~1000 Pa·s which is the value of the slag viscosity capable of yielding the ash deposition ratio of 5~7% or lower.

[0062] Next, using the mixing ratio of the two types of solid fuels as the parameter, the calculator 9 finds, based on the respective compositions of ash components of the solid fuels measured in step S1, the composition of ash components in the resultant solid fuel mixture obtained when two types of solid fuels are mixed (step S4). Then, the calculator 9 calculates the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature based on the compositions of ash components in the resultant solid fuel mixture, compositions which are found in step S4, using the experimentally determined equation (step S5). According to these steps, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature can be found without carrying out any experiment.

[0063] Note that the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature may be calculated based on results of measurement which has been conducted in advance to measure the slag viscosity of slag formed by heating ash of each solid fuel at the predetermined atmospheric temperature. In this way, the slag viscosity adapted to actual conditions of the boiler can be obtained.

[0064] Next, the calculator 9 calculates the mixing ratio of the two types of solid fuels in such a manner that the slag viscosity, which has been calculated in step S5, of the resultant solid fuel mixture at the predetermined atmospheric temperature matches or exceeds the reference value, which has been determined in step S3, and determines the mixing ratio (step S6).

[0065] As such, the slag viscosity of the resultant solid fuel mixture at the predetermined atmospheric temperature is defined as the evaluation index, and the ash adhesion property is evaluated based on that slag viscosity in this embodiment. Then, the mixing ratio of the solid fuels is determined in such a manner that the slag viscosity of the resultant solid fuel mixture matches or exceeds the reference value at the predetermined atmospheric temperature. In this way, even when various types of solid fuels including the low-grade coal are used as fuel, adhesion of ash in the boiler 7 can be accurately predicted in a simple and convenient way, and can be reduced accordingly.

[0066] Further, based on the relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and the ash deposition ratio, the slag viscosity capable of yielding the ash deposition ratio of 5~7% or lower has a value of 300~1000 Pa·s, and this value is defined as the reference value. Therefore, when the slag viscosity of the

resultant solid fuel mixture is set to 300~1000 Pa·s or greater, the ash deposition ratio can be maintained at or below 5~7%, which makes the ash less prone to adhere in the boiler 7. As a result, adhesion of ash can be favorably reduced.

[0067] Here, in calculation of the slag viscosity, when the atmospheric temperature in the vicinity of the burner 6 where adhesion of ash to the boiler walls notably occurs is used as the predetermined atmospheric temperature, the slag viscosity of slag in ash can be appropriately determined for each part inside the boiler 7. Therefore, the suitable mixing ratio of the two types of solid fuels can be calculated.

[0068] On the other hand, in the calculation of the slag viscosity, when the highest allowable atmospheric gas temperature in accordance with design specifications of the boiler 7 is used as the predetermined atmospheric temperature, the suitable mixing ratio of the two types of solid fuels can be found irrespective of a combustion temperature in the furnace of the boiler 7.

[0069] Next, the two types of solid fuels are mixed based on the mixing ratio of the solid fuels determined in step S6, and pulverized coal obtained by crushing the two types of solid fuels is supplied as fuel to the boiler 7 (step S7). Concretely, the calculator 9 controls the fuel supply amount regulators 3a, 3b based on the mixing ratio of the solid fuels determined in step S6, to thereby regulate the amounts of the solid fuels supplied from the hoppers 1, 2 to the boiler 7. The mixer 4 mixes the two types of solid fuels, the supply amounts of which are regulated by the fuel supply amount regulators 3a, 3b. The crusher 5 crushes the solid fuels mixed in the mixer 4 into the pulverized coal, and supplies the pulverized coal as fuel to the boiler 7. The burner 6 initiates combustion using, as fuel, the pulverized coal supplied together with air from the crusher 5.

EXAMPLE

[0070] Hereinafter, an example of the method and device for reducing adhesion of ash in a boiler will be described.

[0071] In this example, an experiment in which a pulverized coal combustion test furnace (furnace inner diameter of 400 mm, in-furnace effective height of 3650 mm) was used, five types of pulverized coals, which have different compositions of ash components, were used under a condition that a total amount of heat input from city gas for heating was maintained constant at 149 kW was performed. In this example, the predetermined atmospheric temperature used for calculating the slag viscosity was set to 1300° C. Table 1 shows compositions of ash components in the five types of pulverized coals at 1300° C.

TABLE 1

	Coal A	Coal B	Coal C	Coal D	Coal E
Ash contents [wt %-DB]	12.53	6.23	1.76	2.73	5.5
SiO ₂ [wt %-ash]	69.8	56.9	40	52	53
Al ₂ O ₃ [wt %-ash]	20.73	23	27.85	20.3	23.5
CaO [wt %-ash]	0.48	2.19	3.7	6.03	3.1
TiO ₂ [wt %-ash]	1.03	0.57	0.56	1.08	1
Fe ₂ O ₃ [wt %-ash]	4.95	11.8	19.95	12.1	9
MgO [wt %-ash]	0.66	2.27	1.21	1.9	2.7
Na ₂ O [wt %-ash]	0.25	0.04	0.14	0.39	0.6
K ₂ O [wt %-ash]	0.98	0.44	0.4	0.67	2.1
P ₂ O ₅ [wt %-ash]	0.2	0.34	0.05	0.13	0.36

TABLE 1-continued

	Coal A	Coal B	Coal C	Coal D	Coal E
MnO [wt %-ash]	0.05	0.03	0.27	0.06	0.2
V ₂ O ₅ [wt %-ash]	0.05	0.05	0.05	0.02	0
SO ₃ [wt %-ash]	0.4	1.27	3.8	5.24	4.6

[0072] In the experiment, two types of the pulverized coals were mixed, and the supply amount of a resultant pulverized coal mixture was adjusted in such a manner that the amount of heat input by the resultant pulverized coal mixture was maintained constant at 60 kW. The resultant pulverized coal mixture was burned together with combustion air by means of a burner installed at the top of the pulverized coal combustion test furnace. Here, an ash adhesion probe was inserted into the furnace so that the ash adhesion probe was positioned below the burner, and the ash adhesion probe was held in this state for 100 minutes. Ash deposition ratio was examined for the ash adhering to the surface of the ash adhesion probe. The atmospheric temperature inside the pulverized coal combustion test furnace in a region where the ash adhesion probe was inserted was approximately 1300° C. equal to the temperature at which an ash adhering phenomenon occurs in an in-service boiler. Further, the interior of the ash adhesion probe was cooled with water so that a surface temperature of the ash adhesion probe was adjusted to approximately 500° C.

[0073] After that, the slag viscosity of the resultant pulverized coal mixture mixed at 1300° C. was calculated based on the composition of ash components in each pulverized coal listed in Table 1 using the empirically determined equation. FIG. 3 shows a relationship between the slag viscosity at 1300° C. and the ash deposition ratio.

[0074] As shown in FIG. 3, when the slag viscosity of the resultant pulverized coal mixture is higher than 300~1000 Pa·s, the ash deposition ratio becomes 5~7% or lower. Thus, it is shown that the ash deposition ratio sharply increases when the slag viscosity of the resultant pulverized coal mixture is equal to or below 300~1000 Pa·s. This shows that adhesion of ash can be reduced by calculating the mixing ratio of two types of pulverized coals so as to obtain the resultant pulverized coal mixture having the slag viscosity which is equal to or above 300~1000 Pa·s at 1300° C., and determining the mixing ratio.

MODIFICATION OF EMBODIMENT

[0075] Although the embodiment of this invention has been described above, the embodiment is provided merely as an illustrative example, and design details including specific configurations may be changed as appropriate. Further, operation and effect described in the embodiment of the invention are exemplified only as most preferable operation and effect obtained by the present invention, and the present invention is not limited to those described in the embodiment.

[0076] For example, although a scheme of determining the reference value based on the relationship between the previously measured slag viscosity and the ash deposition ratio has been described in the embodiment, the determination of the reference value is not limited to the scheme. In a case where a combustion test is conducted using a combustion test furnace or an in-service boiler while changing the viscosity of slag contained in fuel, the reference value may be determined from a slag viscosity obtained when a lump of clinker (molten slag), which is too large in size to be carried out by a conveyor

(not illustrated) installed in the boiler 7, falls on the furnace wall. Alternatively, the reference value may be determined from a slag viscosity obtained when a main steam temperature/pressure deviates from a defined range or fluctuate beyond the range.

[0077] This application is based on Japan Patent Application (NO. 2009-234852) filed on Oct. 9, 2009, which is incorporated herein by reference in its entirety.

DESIGNATION OF REFERENCE CHARACTERS

[0078] 1, 2 hopper

[0079] 3a, 3b fuel supply amount regulator (fuel supply amount regulating means)

[0080] 4 mixer

[0081] 5 crusher

[0082] 6 burner

[0083] 7 boiler

[0084] 9 calculator (calculating means)

[0085] 10 device for reducing adhesion of ash

1. A method for reducing adhesion of ash in a boiler, comprising:

determining, when one or more types of solid fuels are mixed, a mixing ratio of each solid fuel calculated so as to obtain a resultant solid fuel mixture having a slag viscosity that matches or exceeds a reference value at a predetermined atmospheric temperature, and supplying the solid fuels mixed based on the mixing ratio as fuel to the boiler.

2. The method for reducing adhesion of ash in a boiler according to claim 1, wherein the slag viscosity is calculated based on a composition of ash components in the resultant solid fuel mixture.

3. The method for reducing adhesion of ash in a boiler according to claim 1, wherein the slag viscosity is calculated based on a result of measuring a slag viscosity of slag formed by heating ash of each solid fuel at the predetermined atmospheric temperature.

4. The method for reducing adhesion of ash in a boiler according to claim 1, wherein the reference value is a value of the slag viscosity which is, with reference to a relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and ash deposition ratio, associated with the ash deposition ratio of a predetermined value or lower.

5. The method for reducing adhesion of ash in a boiler according to claim 4, wherein the reference value lies between 300 and 1000 Pa·s which are values of the slag viscosity associated with the ash deposition ratio of 5~7% or lower.

6. The method for reducing adhesion of ash in a boiler according to claim 1, wherein the predetermined atmospheric temperature is an atmospheric temperature in a region close to a burner for burning each solid fuel.

7. The method for reducing adhesion of ash in a boiler according to claim 1, wherein the predetermined atmospheric temperature is a highest atmospheric temperature allowed by boiler design.

8. A device for reducing adhesion of ash in a boiler, comprising:

a calculating means which determines, when one or more types of solid fuels are mixed, a mixing ratio of the solid fuels calculated so as to obtain a resultant solid fuel mixture having a slag viscosity that matches or exceeds a reference value at a predetermined atmospheric temperature, and

a fuel supply amount regulating means which regulates an amount of each solid fuel supplied to the boiler based on the mixing ratio.

9. The device for reducing adhesion of ash in a boiler according to claim 8, wherein the slag viscosity is calculated based on a composition of ash components in the resultant solid fuel mixture.

10. The device for reducing adhesion of ash in a boiler according to claim 8, wherein the slag viscosity is calculated based on a result of measuring a slag viscosity of slag formed by heating ash of each solid fuel at the predetermined atmospheric temperature.

11. The device for reducing adhesion of ash in a boiler according to claim 8, wherein the reference value is a value of the slag viscosity which is, with reference to a relationship between the slag viscosity of each solid fuel at the predetermined atmospheric temperature and an ash deposition ratio, associated with the ash deposition ratio of a predetermined value or lower.

12. The device for reducing adhesion of ash in a boiler according to claim 11, wherein the reference value lies between 300 and 1000 Pa·s which are values of the slag viscosity associated with the ash deposition ratio of 5~7% or lower.

13. The device for reducing adhesion of ash in a boiler according to claim 8, wherein the predetermined atmospheric temperature is an atmospheric temperature in a region close to a burner for burning each solid fuel.

14. The device for reducing adhesion of ash in a boiler according to claim 8, wherein the predetermined atmospheric temperature is a highest atmospheric temperature allowed by boiler design.

* * * * *