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(19) **United States**(12) **Patent Application Publication**
MATSUSHITA et al.(10) **Pub. No.: US 2022/0120441 A1**(43) **Pub. Date: Apr. 21, 2022**(54) **POWDER FUEL COMBUSTION APPARATUS
AND COMBUSTION METHOD**(52) **U.S. Cl.**CPC *F23N 5/20* (2013.01); *F23C 6/04*
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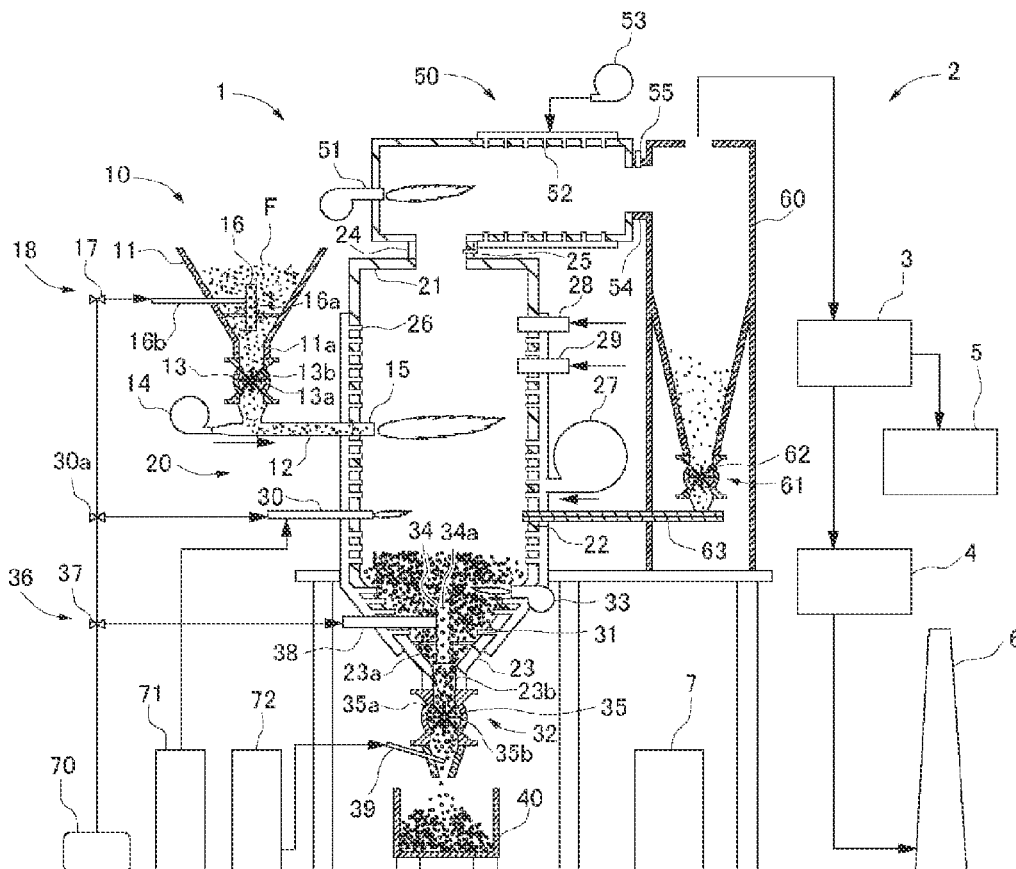
The invention provides a combustion apparatus and a combustion method capable of ashing matter to be combusted inside a combustion chamber efficiently without providing a device such as an unburned combustibles measurement device and without varying the direction of injection of air into the combustion chamber. The powder fuel combustion apparatus 1 includes a fuel supply device 10, a primary combustion chamber 20, a secondary combustion chamber 50, an air supply/ash discharge device 32, and a cyclone dust collector 60. An inclined portion 23a is formed at a bottom portion 23 of the primary combustion chamber 20, and the inclined portion 23a includes bottom portion air supply ports 31 and an air supply/ash discharge device 32. The air supply/ash discharge device 32 includes a bottom portion air injection nozzle 34 and an ash delivery device 35. The bottom portion air injection nozzle 34 has upper and lower ends opened, and a plurality of injection ports 34a through which air is injected are formed on a side surface. During combustion of the powder fuel F, air having a strong wind pressure is injected through the bottom portion air injection nozzle 34 either regularly or irregularly to agitate the powder fuel F and achieve a good combustion state.

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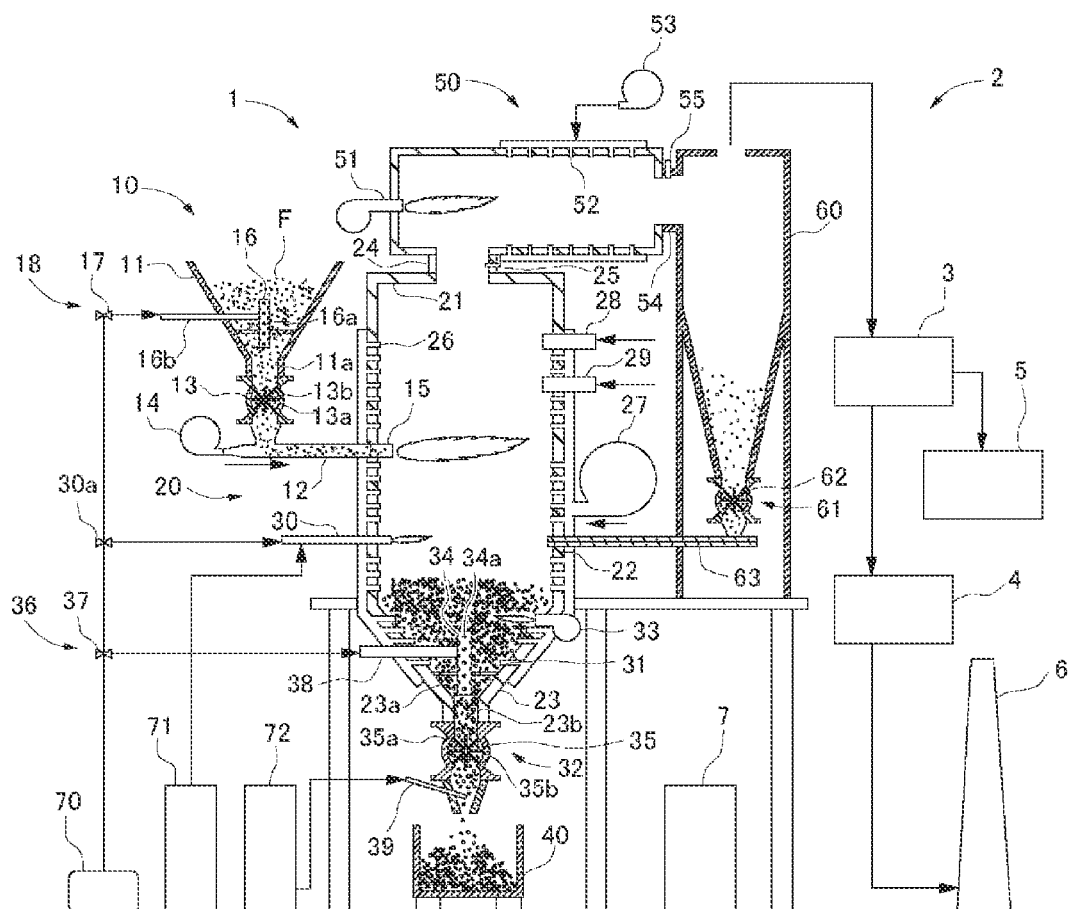


FIG. 1

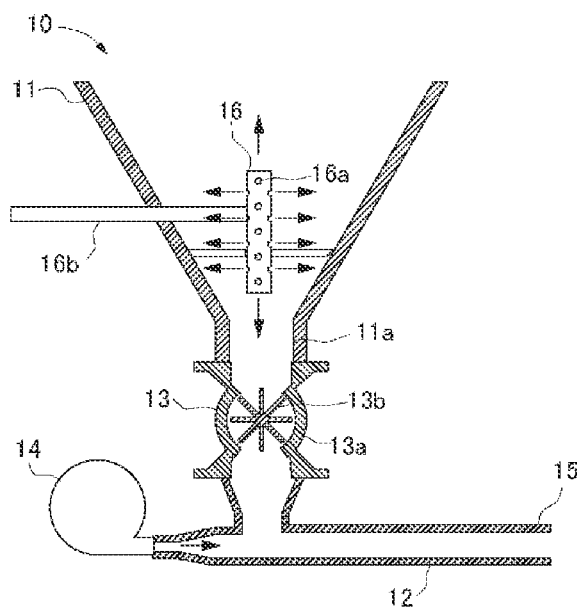


FIG. 2

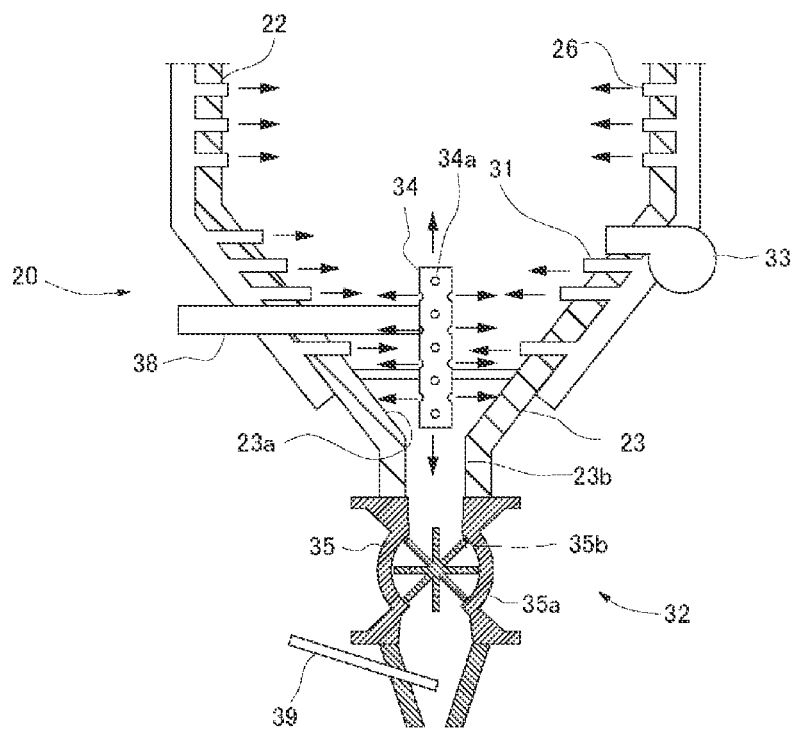


FIG. 3

POWDER FUEL COMBUSTION APPARATUS AND COMBUSTION METHOD

FIELD OF THE INVENTION

[0001] The present invention relates to a combustion apparatus for combusting powder fuel, and a combustion method of the combustion apparatus.

BACKGROUND OF THE INVENTION

[0002] Hitherto, a boiler that uses pulverized coal as fuel to perform combustion and recover combustion heat to supply superheated vapor to power plants and the like is known (refer to Patent Literature 1). The boiler according to Patent Literature 1 includes a furnace having a hollow shape and disposed along a vertical direction, and three combustion burners arranged in the vertical direction to inject pulverized coal mixture and the like obtained by mixing solid fuel and combustion air into the furnace.

[0003] Further, the boiler includes a furnace bottom air nozzle that injects combustion air into the furnace below the combustion burner in the vertical direction and a horizontal direction adjustment device capable of adjusting a direction of injection of combustion air through the furnace bottom air nozzle in the horizontal direction. The boiler according to Patent Literature 1 adopts such a configuration to promote combustion of fuel inside the furnace and suppress generation of unburned combustibles.

[0004] The boiler according to Patent Literature 1 uses, as disclosed for example in paragraphs 0027 and 0051 of the Publication, pulverized coal formed by mainly pulverizing coal as powder fuel (solid fuel).

[0005] Meanwhile, the present inventors utilize a carbonized fuel production apparatus and a carbonized fuel production method disclosed in Patent Literature 2 to produce a high quality carbonized fuel using synthetic resin and the like that has been recovered mainly for reuse as material.

[0006] According to the carbonized fuel production apparatus and the carbonized fuel production method disclosed in Patent Literature 2, even if the quality of the synthetic resin having been recovered is not good and the synthetic resin is not suitable for reuse, it can still be formed into carbonized fuel having a calory close to that of coal. Therefore, even synthetic resin that has been recovered but is not suitable for reuse or synthetic resin that had been disposed as landfill disposal can be regenerated as high quality fuel, so that advantageous effects of recycling synthetic resin and reducing the load applied on landfill disposal sites can be achieved.

PRIOR ART LITERATURE

Patent Literature

[0007] [Patent Document 1] Japanese Patent Laid-Open Application No. 2017-145976

[0008] [Patent Document 2] International Publication No. WO 2018/074189

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

[0009] The boiler according to Patent Literature 1 includes three combustion burners arranged in a vertical direction in a vertically long furnace, and pulverized coal is combusted

inside the furnace, wherein unburned matter is accumulated at a bottom portion of the furnace. According to Patent Literature 1, combustion air is introduced through the furnace bottom air nozzle to the pulverized coal accumulated at the bottom portion of the furnace to thereby burn the unburned matter at the bottom of the furnace.

[0010] According further to the boiler disclosed in Patent Literature 1, as illustrated in FIG. 9 of the publication, a hopper for storing ashes and unburned combustibles is provided at the bottom of the furnace. According to the boiler 1 of Patent Literature 1, ashes and unburned combustibles stored in the hopper are analyzed by an unburned combustibles measurement device and an unburned combustibles analyzing device provided at the bottom of the hopper so as to adjust a direction of injection of air through the furnace bottom air nozzle and reduce the amount of unburned combustibles.

[0011] The unburned combustibles measurement device, the unburned combustibles analyzing device or the configuration of varying the direction of injection of the air nozzle as disclosed in Patent Literature 1 are adoptable in large-scale plants from viewpoints of both technique and costs. However, in a small apparatus, the configuration of the apparatus becomes complex and installation costs are increased. Moreover, such measurement devices and variable mechanism for the nozzle require daily maintenance operations, and the running costs are also undesirably increased.

[0012] In order to solve the problems mentioned above, the present invention aims at providing a combustion apparatus and a combustion method capable of efficiently ashing matter to be combusted in a combustion chamber without installing the unburned combustibles measurement device or the unburned combustibles analyzing device and without varying the direction of injection of air into the combustion chamber.

Means for Solving the Problem

[0013] In order to achieve the above-mentioned object, the powder fuel combustion apparatus according to the present invention is a combustion apparatus for combusting a powder fuel, including a primary combustion chamber configured to combust the powder fuel in an interior thereof, and a secondary combustion chamber configured to combust a combustion gas discharged from the primary combustion chamber, wherein the primary combustion chamber comprises a fuel supply device configured to supply the powder fuel to an interior thereof, a primary air supply port configured to supply air to an interior thereof, and an ignition burner configured to ignite the powder fuel in an interior thereof, wherein a bottom portion of the primary combustion chamber comprises an inclined portion inclined to narrow toward a lower direction, a bottom portion air supply port configured to supply air to an interior thereof, an ash outlet provided to a lower position of the inclined portion, and a bottom portion air injection nozzle having a tubular shape and arranged in a vertical direction, the bottom portion air injection nozzle comprising openings formed on an upper end and a lower end thereof, the lower end positioned toward the ash outlet, and having air supplied to an interior thereof, wherein the secondary combustion chamber comprises a secondary burner configured to heat an interior thereof and ignite a combustion gas discharged from the primary combustion chamber, and a secondary air supply

port configured to supply combustion air to an interior thereof, a primary air supply device configured to supply air to the primary air supply port and the bottom portion air supply port, an injection air supply device configured to supply air to the bottom portion air injection nozzle, and a secondary air supply device configured to supply air to the secondary air supply port, and a controller configured to control operation of the fuel supply device, the ignition burner, the secondary burner, the primary air supply device, the injection air supply device, and the secondary air supply device.

[0014] The controller is configured to accumulate a predetermined amount of the powder fuel to the primary combustion chamber by the fuel supply device, ignite the powder fuel being accumulated using the ignition burner and activate the secondary burner to heat the interior of the secondary combustion chamber, upon performing gasification combustion of the powder fuel being accumulated, activate the primary air supply device and the injection air supply device to supply an amount of air that is smaller than an amount of air necessary for complete combustion of the powder fuel being accumulated through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle to generate flammable gas inside the primary combustion chamber, upon performing direct combustion of the powder fuel being accumulated, activate the primary air supply device and the injection air supply device to supply an amount of air necessary for direct combustion of the powder fuel into the primary combustion chamber through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle, and activate the fuel supply device to supply the powder fuel into the primary combustion chamber and combust the powder fuel and activate the fuel supply device as a burner, and upon performing gasification combustion of the powder fuel being accumulated and performing direct combustion of the powder fuel being accumulated, activate the secondary air supply device to supply an amount of secondary combustion air necessary to perform complete combustion of the flammable gas through the secondary air supply port to combust the flammable gas.

[0015] According to the powder fuel combustion apparatus of the present invention, upon performing gasification combustion of accumulated powder fuel, air is supplied through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle fixed to the primary combustion chamber to generate flammable gas inside the primary combustion chamber, so that air is injected not only through the primary air supply port and the bottom portion air supply port but also through the bottom portion air injection nozzle. Complete combustion of powder fuel can be performed by the above-mentioned configuration according to the present invention, so that analyzing of unburnt components and change of angle of primary air supply nozzle and the like become unnecessary.

[0016] Further, according to the powder fuel combustion apparatus of the present invention, upon performing ember combustion and ashing of the powder fuel in the primary combustion chamber, supply of fuel by the fuel supply device can be stopped, and supply of air from the bottom portion air injection nozzle can also be stopped.

[0017] According to the powder fuel combustion apparatus of the present invention, when ember combustion and ashing of the powder fuel in the primary combustion cham-

ber are performed, white smoke may occur in the primary combustion chamber and the secondary combustion chamber depending on the component of the powder fuel, and load may be applied on devices such as a cyclone dust collector and a bag filter arranged downstream of the secondary combustion chamber.

[0018] Through earnest investigation, the present inventors have discovered that regarding the occurrence of white smoke during ember combustion and ashing, the occurrence of white smoke can be prevented by stopping the supply of air through the bottom portion air injection nozzle, without adopting the method of heating the interior of the primary combustion chamber and the secondary combustion chamber using a stabilizing burner or a secondary burner. Therefore, upon performing ember combustion and ashing of the powder fuel inside the primary combustion chamber, if white smoke occurred in the primary combustion chamber and the secondary combustion chamber, the supply of air through the bottom portion air injection nozzle should merely be stopped.

[0019] Further according to the powder fuel combustion apparatus of the present invention, upon performing gasification combustion of the powder fuel being accumulated and upon performing direct combustion of the powder fuel being accumulated, the controller can control the injection air supply device so as to inject air by an amount of injection capable of agitating the powder fuel either regularly or irregularly through the bottom portion air injection nozzle.

[0020] According to this control, the powder fuel is agitated by the air injected either regularly or irregularly through the bottom portion air injection nozzle, so that the powder fuel can be prevented from being fixed to the wall surface of the bottom of the furnace, and the powder fuel can be combusted efficiently.

[0021] Further according to the powder fuel combustion apparatus of the present invention, the fuel supply device includes a fuel hopper through which the powder fuel is loaded, a hopper injection nozzle arranged in a vertical direction in the fuel hopper to inject air at least to a lower direction thereof, a hopper air supply device configured to supply air to the hopper injection nozzle, a fuel delivery device arranged at a lower direction of the hopper injection nozzle and delivering the powder fuel to the lower direction, a mixing pipe in which the powder fuel and air are mixed, and a fuel blower configured to supply air to the mixing pipe, and upon supplying the powder fuel to the primary combustion chamber, the controller can to activate the fuel blower and also activate the fuel delivery device, mix the powder fuel and air supplied from the fuel blower in an interior of the mixing pipe and supply the powder fuel from the mixing pipe to the primary combustion chamber, and activate the hopper air supply device at a predetermined timing to inject air through the hopper injection nozzle.

[0022] According to the present configuration, the powder fuel in the fuel hopper can be delivered smoothly to the fuel delivery device by the hopper air supply device, and the powder fuel can be supplied stably into the primary combustion chamber through the mixing pipe.

[0023] Further, the powder fuel combustion method of the present invention is a combustion method of combusting a powder fuel by a powder fuel combustion apparatus, including a fuel charging step, an igniting step, a gasification combustion step, a direct combustion step, and an ember-ashing step, wherein the powder fuel combustion apparatus

includes a primary combustion chamber configured to combust the powder fuel in an interior thereof, and a secondary combustion chamber configured to combust a gas discharged from the primary combustion chamber, wherein the primary combustion chamber includes a fuel supply device configured to supply the powder fuel to an interior thereof, a primary air supply port configured to supply air to an interior thereof, and an ignition burner configured to ignite the powder fuel in an interior thereof, wherein a bottom portion of the primary combustion chamber includes an inclined portion inclined to narrow toward a lower direction, a bottom portion air supply port configured to supply air to an interior thereof, an ash outlet provided to a lower position of the inclined portion, and a bottom portion air injection nozzle having a tubular shape and arranged in a vertical direction, the bottom portion air injection nozzle including openings formed on an upper end and a lower end thereof, the lower end positioned toward the ash outlet, and having air supplied to an interior thereof and ignite the combustion gas discharged from the primary combustion chamber, wherein the secondary combustion chamber comprises a secondary burner configured to heat an interior thereof, and a secondary air supply port configured to supply combustion air to an interior thereof, a primary air supply device configured to supply air to the primary air supply port and the bottom portion air supply port, an injection air supply device configured to supply air to the bottom portion air injection nozzle, a secondary air supply device configured to supply air to the secondary air supply port, and a controller configured to control operation of the fuel supply device, the ignition burner, the secondary burner, the primary air supply device, the injection air supply device, and the secondary air supply device.

[0024] The controller is configured to accumulate a predetermined amount of the powder fuel in the primary combustion chamber by the fuel supply device in the fuel charging step, heat the interior of the secondary combustion chamber by the secondary burner, and after the interior of the secondary combustion chamber has reached a predetermined temperature, ignite the powder fuel being accumulated using the ignition burner in the igniting step, supply an amount of air that is smaller than an amount of air necessary for complete combustion of the powder fuel being accumulated through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle to generate flammable gas inside the primary combustion chamber, introduce the flammable gas to the secondary combustion chamber, and perform complete combustion of the flammable gas by supplying air for secondary combustion through the secondary air supply port in the gasification combustion step, activate the primary air supply device and the injection air supply device to supply an amount of air necessary for direct combustion of the powder fuel into the primary combustion chamber through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle, activate the fuel supply device to supply the powder fuel into the primary combustion chamber and combust the powder fuel to activate the fuel supply device as a burner, introduce combustion gas discharged from the primary combustion chamber to the secondary combustion chamber, and perform complete combustion of the combustion gas by supplying air for secondary combustion through the secondary air supply port in the direct combustion step, and stop supply of fuel by the

fuel supply device and perform ember combustion and ashing of the powder fuel remaining in the primary combustion chamber in the ember-ashing step.

[0025] The powder fuel combustion method according to the present invention is composed of the fuel charging step, the igniting step, the gasification combustion step, the direct combustion step, and the ember-ashing step. In the gasification combustion step, air is supplied through the primary air supply port, the bottom portion air supply port and the bottom portion air injection nozzle to generate flammable gas inside the primary combustion chamber, so that air is injected not only through the primary air supply port and the bottom portion air supply port but also through the bottom portion air injection nozzle. Therefore, air is injected to the powder fuel accumulated in the interior of the bottom portion that is inclined to narrow toward the lower direction, so that the powder fuel can be combusted infallibly compared to the conventional combustion method.

[0026] According to the powder fuel combustion method of the present invention, in the ember-ashing step, supply of air from the bottom portion air injection nozzle can be stopped. According to this process, the occurrence of white smoke during the ember-ashing step of the powder fuel can be prevented.

[0027] According further to the powder fuel combustion method of the present invention, in the gasification combustion step and the direct combustion step, the controller can control the injection air supply device so that air is injected by an amount of injection capable of agitating the powder fuel to the bottom portion air injection nozzle either regularly or irregularly. According to this control, the powder fuel accumulated at the bottom portion of the primary combustion chamber can be agitated, so that the powder fuel can be combusted infallibly compared to the conventional combustion method.

[0028] Further according to the powder fuel combustion method of the present invention, the fuel supply device includes a fuel hopper through which the powder fuel is loaded, a hopper injection nozzle arranged in a vertical direction in the fuel hopper to inject air at least to a lower direction thereof, a hopper air supply device configured to supply air to the hopper injection nozzle, a fuel delivery device arranged at a lower direction of the hopper injection nozzle and delivering the powder fuel to the lower direction, a mixing pipe in which the powder fuel and air are mixed, and a fuel blower through which air is supplied to the mixing pipe, and in the fuel charging step and the direct combustion step, the controller can activate the fuel blower and also activate the fuel delivery device, mix the powder fuel and air supplied from the fuel blower in an interior of the mixing pipe and supply the powder fuel from the mixing pipe to the primary combustion chamber, and activate the hopper air supply device at a predetermined timing to inject air through the hopper injection nozzle.

[0029] According to the present control, during the fuel charging step and the direct combustion step, the powder fuel in the fuel hopper can be delivered smoothly to the fuel delivery device by the hopper air supply device, so that the powder fuel can be supplied stably to the primary combustion chamber from the mixing pipe.

Advantageous Effects of Invention

[0030] The present invention enables to provide a combustion apparatus and a combustion method capable of

realizing advantageous combustion of powder fuel such as even carbonized fuel mainly composed of recovered synthetic resin and waste plastic.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. 1 is an explanatory view illustrating a power generation system including a powder fuel combustion apparatus according to a present embodiment.

[0032] FIG. 2 is an explanatory view illustrating a fuel supply device according to the powder fuel combustion apparatus of the present embodiment.

[0033] FIG. 3 is an explanatory view illustrating a configuration of a bottom portion of a primary combustion chamber according to the powder fuel combustion apparatus of the present embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0034] Next, a powder fuel combustion apparatus and a powder fuel combustion method according to one example of an embodiment of the present invention will be described with reference to FIGS. 1 to 3. FIG. 1 is an explanatory view illustrating the power generation system including the powder fuel combustion apparatus according to the present embodiment. FIG. 2 is an explanatory view illustrating a fuel supply device in the powder fuel combustion apparatus according to the present embodiment. FIG. 3 is an explanatory view illustrating a configuration of a bottom portion of a primary combustion chamber of the powder fuel combustion apparatus according to the present embodiment. According to the present embodiment, powdered char that is made from waste plastic produced using the carbonized fuel production apparatus disclosed in Patent Literature 2 is used as powder fuel.

[0035] A powder fuel combustion apparatus 1 according to the present embodiment is a combustion apparatus adopted in a power generation system 2 using powder fuel F, as illustrated in FIG. 1. The power generation system 2 includes, in addition to the powder fuel combustion apparatus 1, a boiler 3, a dust collecting device 4, a power generating device 5, a smokestack 6, and a controller 7 for controlling the devices.

[0036] The powder fuel combustion apparatus 1 includes, as illustrated in FIG. 1, a fuel supply device 10, a primary combustion chamber 20, a secondary combustion chamber 50, an air supply/ash discharge device 32, and a cyclone dust collector 60. An outlet of the cyclone dust collector 60 is connected to the boiler 3.

[0037] The primary combustion chamber 20 has an overall cylindrical shape according to the present embodiment, and it is composed of a ceiling portion 21 positioned at an upper portion thereof, a body portion 22 positioned at a lower side of the ceiling portion 21, and a bottom portion 23 positioned at a lower side of the body portion 22.

[0038] A primary exhaust port 24 through which a flammable gas or a combustion gas generated in the primary combustion chamber 20 is discharged is formed to the ceiling portion 21. Further, a first temperature sensor 25 for detecting the temperature of a combustion gas generated in the primary combustion chamber 20 is provided in the primary exhaust port 24. The primary exhaust port 24 can be formed on a top panel of the ceiling portion 21 as illustrated in FIG. 1, or it can be formed on a side wall thereof.

[0039] The fuel supply device 10 is connected to the body portion 22. The fuel supply device 10 includes a fuel hopper 11 through which a powder fuel F is charged, a mixing pipe 12 in which the powder fuel F and combustion air are mixed, a fuel delivery device 13 for supplying the powder fuel F charged in the fuel hopper 11 to the mixing pipe 12 by an arbitrary amount of supply, a blower for fuel 14 for supplying combustion air to the mixing pipe 12, and a burner port 15 disposed at a tip portion of the mixing pipe 12.

[0040] A hopper injection nozzle 16 having a tubular shape and extending in a vertical direction is disposed in a center of the fuel hopper 11. The hopper injection nozzle 16 is a tubular shaped member having upper and lower end portions opened, and a plurality of injection ports 16a are formed on a side surface thereof through which air is injected. A lower end portion of the hopper injection nozzle 16 is disposed toward an opening portion 11a of the fuel hopper 11. Further, a hopper air supply device 18 composed of an air compressor 70, a solenoid valve for fuel 17 and an air supply pipe for fuel 16b is connected to the hopper injection nozzle 16.

[0041] The fuel delivery device 13 of the fuel supply device 10 delivers the powder fuel F by rotation of a rotary valve 13b inside a case 13a having a cylindrical shape. An amount of delivery per time of fuel is controlled by subjecting a motor not shown to inverter control and adjusting a rotational frequency of the rotary valve 13b.

[0042] An amount of air blow of the blower for fuel 14 of the fuel supply device 10 can also be adjusted by subjecting a motor not shown to inverter control. An air-fuel ratio of fuel blown out through the burner port 15 can be changed by adjusting the amount of delivery of the powder fuel F of the fuel delivery device 13 and the amount of air blow of the blower for fuel 14.

[0043] In a state where combustion is performed in the primary combustion chamber 20 of the fuel supply device 10, when the powder fuel F and combustion air are supplied through the burner port 15 to the primary combustion chamber 20, the powder fuel F is ignited near the burner port 15, by which the burner port serves as a burner thereafter to perform combustion.

[0044] Further, a plurality of primary air supply ports 26 for supplying primary combustion air into the primary combustion chamber 20 are provided on a peripheral wall of the body portion 22. Air is supplied to the primary air supply ports 26 from a primary air blower 27 which is a primary air supply device disposed on an outer side of the body portion 22.

[0045] Further, a steam inlet port 28 and a vent gas inlet port 29 are provided on an upper position of the body portion 22. These inlet ports can be used to introduce steam and vent gas into the primary combustion chamber 20 as needed. As for steam, steam containing smell components recovered during production of fuel by a fuel production apparatus disclosed in Patent Literature 2 and the like can be introduced. As for vent gas, gas recovered during production of fuel by the fuel production apparatus disclosed in Patent Literature 2 can be used.

[0046] Further, the body portion 22 is provided with a stabilizing burner 30 that helps combustion inside the primary combustion chamber 20, and a stabilizing solenoid valve 30a for supplying air to the stabilizing burner 30. For example, a vent oil that has been recovered during fuel

production by the fuel production apparatus disclosed in Patent Literature 2 is used as the fuel for the stabilizing burner 30.

[0047] An inclined portion 23a that is inclined to narrow toward the lower direction from a wall surface of the body portion 22 is formed at the bottom portion 23 of the primary combustion chamber 20, and an ash outlet 23b is formed below the inclined portion 23a. The inclined portion 23a is provided with a plurality of bottom portion air supply ports 31 that introduce combustion air to the interior. Air is supplied from the primary air blower 27 to the bottom portion air supply ports 31.

[0048] The bottom portion 23 is further provided with the air supply/ash discharge device 32 that is arranged in the interior of the inclined portion 23a and an ignition burner 33 that ignites the powder fuel F charged in the bottom portion 23. The fuel used in the ignition burner 33 can be kerosene or heavy oil and the like.

[0049] The air supply/ash discharge device 32 includes a bottom portion air injection nozzle 34 and an ash delivery device 35. The bottom portion air injection nozzle 34 is a tubular shaped member extending in the vertical direction, and which is positioned approximately at a center of the inclined portion 23a. The bottom portion air injection nozzle 34 has its upper and lower ends opened, and a plurality of injection ports 34a through which air is injected are provided on the side surface thereof. The lower end portion of the bottom portion air injection nozzle 34 is arranged toward the ash outlet 23b.

[0050] An injection air supply device 36 composed of the air compressor 70 and a bottom portion solenoid valve 37, and a bottom portion air supply pipe 38 are connected to the bottom portion air injection nozzle 34. Air for injection is supplied from the injection air supply device 36 to the bottom portion air injection nozzle 34.

[0051] The ash delivery device 35 delivers ashes by having a rotary valve 35b rotate inside a case 35a having a tubular shape. Further, a water spray nozzle 39 for injecting water into a lower portion of the case 35a is provided on the ash delivery device 35. When water is injected through the water spray nozzle 39, the ashes inside the case 35a are cooled and the ashes are gathered by water, by which the ashes fall downward without being scattered.

[0052] An ash receiver 40 is arranged below the ash outlet 23b to pool the ashes discharged through the ash outlet 23b. The ash receiver 40 is capable of being moved by a moving unit such as a forklift from the position below the ash outlet 23b to an ash recovery location.

[0053] In addition to the above, the powder fuel combustion apparatus 1 is provided with a vent oil tank 71 for supplying vent oil serving as fuel to the stabilizing burner 30, a water tank 72 for supplying water to the water spray nozzle 39, and so on.

[0054] The secondary combustion chamber 50 is a combustion chamber having a cylindrical shape to which is connected the primary exhaust port 24 through which combustion gas of the primary combustion chamber 20 is introduced. A secondary burner 51 for igniting combustion gas is provided near a connecting portion of the primary exhaust port 24. A plurality of secondary air supply ports 52 for supplying secondary combustion air for performing secondary combustion are provided to the peripheral wall of the secondary combustion chamber 50. Air is supplied to the

secondary air supply ports 52 from a secondary air blower 53 serving as a secondary air supply device.

[0055] A secondary exhaust port 54 which is connected to the cyclone dust collector 60 is provided downstream of the secondary combustion chamber 50. The secondary exhaust port 54 is provided with a second temperature sensor 55 for detecting temperature of combustion gas of the secondary combustion chamber 50. Further, a cyclone recovery device 61 is provided below the cyclone dust collector 60.

[0056] The cyclone recovery device 61 is composed of a rotary valve 62 and a screw conveyor 63. Powder dust recovered in the cyclone dust collector 60 is once again returned to the primary combustion chamber 20 by the cyclone recovery device 61 and subjected to combustion.

[0057] The boiler 3 according to the power generation system 2 of the present embodiment is an apparatus that generates superheated vapor and saturated vapor by heat from the exhaust gas subjected to dust collection processing by the cyclone dust collector 60. According to present embodiment, the boiler 3 performs heat recovery from the exhaust gas of approximately 600° C. and lowers the outlet temperature of exhaust gas to approximately 200° C.

[0058] The power generating device 5 is a device that generates electricity by rotating a turbine not shown by steam that has been generated in the boiler 3. A generally used device is adopted as the power generating device 5. The steam generated in the boiler 3 can be utilized not only in the power generating device 5 but also in auxiliary facilities such as a heating equipment.

[0059] The dust collecting device 4 is provided downstream of the boiler 3. A bag filter and the like being widely used in general can be adopted as the dust collecting device 4. Further, a device for lowering the gas temperature and the like can be installed as needed before the bag filter. Even further, other types of dust collectors such as a centrifugal type dust collector, an electric dust collector, or a gravity type dust collector can be adopted as the dust collecting device 4. It may be possible to omit the dust collecting device 4 itself, depending on the scale of the power generation system 2 or the type of fuel being combusted.

[0060] A suction fan not shown is provided on the smokestack 6, and the exhaust gas generated in the powder fuel combustion apparatus 1 is sucked to the smokestack 6 and released to the exterior. The suction fan is also driven by inverter control, and the rotational frequency thereof is controlled by signals from the controller 7.

[0061] The controller 7 is a so-called control panel that includes various operation switches, an indicator showing operating states of respective devices, and a computer for controlling the respective devices (all of which are not shown). The computer of the controller 7 is equipped with a CPU, a storage device, a communication device and so on (all of which are not shown), and the storage device stores programs for executing operation of the power generation system 2 including the powder fuel combustion apparatus 1 according to the present embodiment.

[0062] Next, a combustion method of the powder fuel combustion apparatus 1 according to the present embodiment will be described. The combustion method according to the present embodiment is composed of a fuel charging step, an igniting step, a gasification combustion step, a direct combustion step, and an ember-ashing step. The respective steps are executed by programs stored in the controller 7.

[0063] According to the combustion method of the present embodiment, at first, a fuel charging step is performed. In the fuel charging step, a predetermined amount of powder fuel F is accumulated in the primary combustion chamber 20 using the fuel supply device 10. The amount of powder fuel F is set so that approximately one-third of a capacity of the primary combustion chamber 20 is filled. The predetermined amount should preferably be approximately one-fourth to one-half of the primary combustion chamber 20 considering operating efficiency of the powder fuel combustion apparatus 1, but it can be varied arbitrarily according to the property of the powder fuel F.

[0064] In the fuel charging step, at first, the fuel supply device 10 is started in a state where the powder fuel F is charged in the fuel hopper 11 of the fuel supply device 10. The charging of the powder fuel F to the fuel hopper 11 can be controlled by the controller 7 using a conveyor, or by manually operating the conveyor or the like.

[0065] When the fuel supply device 10 is started by the controller 7, the rotary valve 13b is rotated and the powder fuel F in the fuel hopper 11 is conveyed to the lower part of the case 13a by the rotary valve 13b. In this state, air for injection is sent at a predetermined timing from the hopper air supply device 18 to the hopper injection nozzle 16 in the fuel hopper 11. Thereby, the powder fuel F in the fuel hopper 11 is conveyed to the lower part of the case 13a by the rotary valve 13b without causing bridging or the like.

[0066] The timing for activating the hopper air supply device 18 can be varied arbitrarily according to the state of the powder fuel F, and for example, the hopper air supply device 18 can be activated every one to ten minutes or can be activated each time the powder fuel F is added to the fuel hopper 11.

[0067] Meanwhile, the operation of the blower for fuel 14 is also started, and air is supplied to the mixing pipe 12. The powder fuel F and the supplied air are mixed in the mixing pipe 12 and discharged frontward through the burner port 15.

[0068] In this state, the ignition burner 33 and the stabilizing burner 30 are not activated in the primary combustion chamber 20, so that the powder fuel F discharged from the fuel supply device 10 is accumulated at the bottom portion 23 of the primary combustion chamber 20. The operation of the fuel supply device 10 is continued until approximately one-third of the capacity of the primary combustion chamber 20 is filled, and after a predetermined amount of the powder fuel F has been supplied, the operation of the fuel supply device 10 is stopped.

[0069] Next, according to the combustion method of the present embodiment, the igniting step is performed. In the igniting step, at first, combustion of the secondary burner 51 of the secondary combustion chamber 50 is started, and the temperature inside the secondary combustion chamber 50 is raised. After the temperature of the secondary combustion chamber 50 has reached a predetermined temperature (such as 800° C.), the ignition burner 33 is activated to ignite the powder fuel F accumulated in the primary combustion chamber 20. In this state, if ignition of the powder fuel F accumulated in the primary combustion chamber 20 has been confirmed via the first temperature sensor 25, the ignition burner 33 is stopped.

[0070] Next, the gasification combustion step will be described. In the gasification combustion step, a part of the powder fuel F charged during the fuel charging step is

combusted in the primary combustion chamber 20 and generates flammable gas. Primary combustion air is supplied to the primary combustion chamber 20 through the primary air blower 27, the primary air supply ports 26 and the bottom portion air supply ports 31.

[0071] In the gasification combustion step, an amount of air smaller than the amount of air necessary for complete combustion of the powder fuel F is supplied as the primary combustion air introduced to the primary combustion chamber 20. Therefore, in the primary combustion chamber 20, a portion of the powder fuel F is combusted and heats the surrounding powder fuel F to gradually expand the combustion range, so that flammable gas is generated from the powder fuel F.

[0072] Air is supplied intermittently to the primary combustion chamber 20 from the bottom portion air injection nozzle 34 of the air supply/ash discharge device 32. Air is injected through upper and lower end portions and injection ports 34a of the bottom portion air injection nozzle 34. In this state, for example, control is performed to inject a minute amount of air for a predetermined time and to increase the amount of injection either regularly or irregularly. Specifically, a small amount of air that will not cause wind pressure that moves the powder fuel F near the bottom portion air injection nozzle 34 is injected for five minutes, and once every five minutes, strong air capable of agitating the powder fuel F around the bottom portion air injection nozzle 34 is injected.

[0073] The injection of air is not limited to regular injection performed every five minutes, for example, and air can be injected normally at a weak wind pressure, wherein if the temperature inside the primary combustion chamber 20 becomes equal to or lower than a predetermined temperature, the injection of air can be performed at such a strength that the powder fuel F is agitated. By injecting air intermittently through the upper and lower opening portions of the bottom portion air injection nozzle 34 and the injection ports 34a provided on the side walls thereof, the powder fuel F accumulated at the bottom portion 23 of the primary combustion chamber 20 is agitated and preferable combustion is performed.

[0074] If flammable gas from the primary combustion chamber 20 is discharged into the heated secondary combustion chamber 50 during the gasification combustion step, the flammable gas is ignited by the secondary burner 51, and complete combustion is performed inside the secondary combustion chamber 50.

[0075] According to the present embodiment, control is performed so that the combustion temperature inside the secondary combustion chamber 50 is set to 800° C. or higher, preferably 900° C. or higher. The secondary burner 51 stops operating if the temperature detected by the second temperature sensor becomes equal to the predetermined temperature or higher, but even thereafter, combustion in the secondary combustion chamber 50 is continued by the flammable gas from the primary combustion chamber 20.

[0076] In the gasification combustion step, the controller 7 performs control so that the combustion temperature inside the secondary combustion chamber 50 is approximately constant. The control of combustion temperature inside the secondary combustion chamber 50 is performed by adjusting the amount of primary air supplied by the primary air blower 27 in a state where a constant amount of secondary

air necessary for complete combustion of flammable gas is supplied from the secondary air blower 53.

[0077] Further in that state, the combustion temperature inside the secondary combustion chamber 50 can be controlled by controlling combustion by the stabilizing burner 30. Meanwhile, even if steam is supplied from the steam inlet port 28 and vent gas is introduced through the vent gas inlet port 29, the combustion temperature inside the secondary combustion chamber 50 can be controlled by adjusting the amount of primary air supplied by the primary air blower 27.

[0078] After complete combustion inside the secondary combustion chamber 50, the exhaust gas is discharged through the secondary exhaust port 54 and passed through the cyclone dust collector 60 to be introduced to the boiler 3. In the cyclone dust collector 60, the powder dust contained in the exhaust gas is separated and dropped to the bottom portion of the cyclone dust collector 60. The powder dust dropped to the bottom portion is returned to the primary combustion chamber 20 by the rotary valve 62 and the screw conveyor 63 of the cyclone recovery device 61 and subjected to combustion.

[0079] The exhaust gas from which powder dust has been removed as described above has a high temperature in the secondary exhaust port 54, but it is subjected to heat exchange at the boiler 3 and the temperature thereof drops before being passed through the dust collecting device 4 and the smokestack 6 to be discharged to the outer air.

[0080] In the boiler 3, steam is generated by the heat of exhaust gas after combustion, and the steam is used to generate power in the power generating device 5. According to the present embodiment, char made from recovered plastic produced by the carbonized fuel production apparatus according to Patent Literature 2 is used as the powder fuel F. As described, according to the power generating device 5, the powder fuel F serving as fuel is made from recovered plastic, and the recovered plastic is used to generate power, so that power can be generated with extremely small environmental load.

[0081] When the gasification combustion step is continued for a predetermined time, the powder fuel F accumulated in the primary combustion chamber 20 is gradually switched from gasification combustion to direct combustion. The switching of the combustion state is determined based on the temperature inside the primary combustion chamber 20 and the temperature condition inside the secondary combustion chamber 50.

[0082] Specifically, in a state where the temperature inside the primary combustion chamber 20 is either maintained or rising, the gradual switching from gasification combustion to direct combustion is detected at a timing at which the temperature of the secondary combustion chamber 50 starts to drop. According to the control performed by the controller 7, the amount of primary air supplied by the primary air blower 27 is adjusted to make the combustion temperature inside the secondary combustion chamber 50 constant.

[0083] When combustion of powder fuel F inside the primary combustion chamber 20 advances, powder fuel F is gradually reduced, so that the controller 7 performs control to increase the rotational frequency of the primary air blower 27 to increase flammable gas. If this state is advanced, the amount of powder fuel F that has decreased in the primary combustion chamber 20 and the amount of primary air having been increased approaches an appropriate air-fuel

ratio and approximates complete combustion, so that the amount of flammable gas sent into the secondary combustion chamber 50 is reduced and the temperature inside the secondary combustion chamber 50 starts to drop. When such drop of temperature in the secondary combustion chamber 50 is detected, the controller 7 determines that the combustion state has switched.

[0084] According to the combustion method of the present embodiment, when the gasification combustion step ends, the procedure advances to the direct combustion step. In the direct combustion step, the powder fuel F accumulated in the bottom portion 23 of the primary combustion chamber 20 continues combustion by direct combustion. In this state, air is supplied through the bottom portion air supply ports 31 and air is also injected intermittently through the bottom portion air injection nozzle 34.

[0085] In the direct combustion step, the powder fuel F is supplied from the fuel supply device 10. When the powder fuel F is supplied from the fuel supply device 10, the temperature inside the primary combustion chamber 20 is in a state exceeding the ignition temperature of the powder fuel F, so that the powder fuel F injected from the burner port 15 is ignited and continuous combustion is realized. As described, in the direct combustion step, the fuel supply device 10 serves as a burner for powder fuel.

[0086] The powder fuel F injected from the fuel supply device 10 is supplied into the primary combustion chamber 20 while being combusted, wherein the combusted component is discharged as combustion gas to the secondary combustion chamber 50, and the yet-to-be-combusted portion is accumulated inside the primary combustion chamber 20 while being combusted. Further, the powder fuel F supplied into the primary combustion chamber 20 is continuously combusted by the combustion air supplied through the primary air supply ports 26 and the bottom portion air injection nozzle 34, and gradually ashed.

[0087] According to the combustion method of the present embodiment, after the direct combustion step is ended, the procedure advances to an ember-ashing step. When ending the direct combustion step, the supply of powder fuel F by the fuel supply device 10 is stopped. Thereby, combustion inside the primary combustion chamber 20 is performed only by the powder fuel F accumulated in the bottom portion 23 of the primary combustion chamber 20, and combustion is gradually transited from direct combustion to ember combustion, and when ember combustion is continued, the powder fuel F is gradually ashed.

[0088] In this state, the injection of air from the bottom portion air injection nozzle 34 is stopped, and air is supplied only through the primary air supply ports 26 and the bottom portion air supply ports 31. As described, by stopping the injection of air through the bottom portion air injection nozzle 34, occurrence of white smoke of exhaust gas discharged from the secondary combustion chamber 50 can be prevented.

[0089] In the ember-ashing step, since combustion of powder fuel F advances to ember combustion, the remaining powder fuel F is gradually ashed, and in the end, it is almost completely ashed. The ashing of powder fuel F inside the primary combustion chamber 20 can be detected by detecting the temperature inside the primary combustion chamber 20 by the first temperature sensor 25.

[0090] Ashes of the powder fuel F having been ashed are discharged to the exterior of the primary combustion cham-

ber 20 by the ash delivery device 35 of the air supply/ash discharge device 32. In the ash delivery device 35, the rotary valve 35b is rotated to discharge the ashes at the bottom portion 23 of the primary combustion chamber 20 through the ash outlet 23b to the exterior. In that state, air is injected strongly through the bottom portion air injection nozzle 34 intermittently, so that the ashes accumulated in the bottom portion 23 is discharged smoothly to the exterior.

[0091] Water is injected through the water spray nozzle 39 at the lower portion of the case 35a to the ashes discharged from the ash outlet 23b, so that the temperature of the ashes in the case 35a is lowered and ashes are gathered by water, thereby dropping down without being scattered. The ash receiver 40 is arranged below the ash outlet 23b to store the ashes discharged through the ash outlet 23b and deliver the ashes to a recovery location via a forklift and the like as needed.

[0092] As described, in the powder generation system 2 including the powder fuel combustion apparatus 1 of the present invention, complete combustion of the powder fuel F is performed by supplying primary air through the fixed bottom portion air injection nozzle 34 and the bottom portion air supply ports 31. There is no need to analyze the unburned combustibles as according to Patent Literature 1, and there is also no need to vary the supply angle of primary air.

[0093] According further to the powder fuel combustion apparatus 1 of the present invention, air is injected intermittently to the powder fuel F at the bottom portion 23 of the primary combustion chamber 20 through the bottom portion air injection nozzle 34 of the air supply/ash discharge device 32, so that the powder fuel F can be combusted and ashed infallibly without being accumulated at the bottom of the furnace, and discharged to the exterior of the primary combustion chamber 20. Therefore, the powder fuel combustion apparatus 1 according to the present invention can combust the powder fuel F infallibly and perform energy recovery of the power generating device 5 efficiently.

[0094] [Reference Numbers]

[0095] 1: powder fuel combustion apparatus, 2: power generation system, 3: boiler, 4: dust collecting device, 5: power generating device, 6: smokestack, 7: controller, 10: fuel supply device, 11: fuel hopper, 11a: opening portion, 12: mixing pipe, 13: fuel delivery device, 13a: case, 13b: rotary valve, 14: blower for fuel, 15: burner port, 16: hopper injection nozzle, 16a: injection port, 17: solenoid valve for fuel, 18: hopper air supply device, 20: primary combustion chamber, 21: ceiling portion, 22: body portion, 23: bottom portion, 23a: inclined portion, 23b: ash outlet, 24: primary exhaust port, 25: first temperature sensor, 26: primary air supply port, 27: primary air blower, 28: steam inlet port, 29: vent gas inlet port, 30: stabilizing burner, 31: bottom portion air supply port, 32: air supply/ash discharge device, 33: ignition burner, 34: bottom portion air injection nozzle, 34a: injection port, 35: ash delivery device, 35a: case, 35b: rotary valve, 36: injection air supply device, 37: bottom portion solenoid valve, 38: bottom portion air supply pipe, 39: water spray nozzle, 40: ash receiver, 50: secondary combustion chamber, 51: secondary burner, 52: secondary air supply port, 53: secondary air blower, 54: secondary exhaust port, 55: second temperature sensor, 60: cyclone dust collector, 61: cyclone recovery device, 62: rotary valve, 63: screw conveyor, 70: air compressor, 71: vent oil tank, 72: water tank.

1. A combustion apparatus for combusting a powder fuel, comprising:

a primary combustion chamber configured to combust the powder fuel in an interior thereof, and a secondary combustion chamber configured to combust a combustion gas discharged from the primary combustion chamber,

wherein the primary combustion chamber comprises a fuel supply device configured to supply the powder fuel to an interior thereof, a primary air supply port configured to supply air to an interior thereof, and an ignition burner configured to ignite the powder fuel in an interior thereof,

wherein a bottom portion of the primary combustion chamber comprises an inclined portion inclined to narrow toward a lower direction, a bottom portion air supply port configured to supply air to an interior thereof, an ash outlet provided at a lower position of the inclined portion, and a bottom portion air injection nozzle having a tubular shape and arranged in a vertical direction, the bottom portion air injection nozzle comprising openings formed on an upper end and a lower end thereof, the lower end positioned toward the ash outlet, and having air supplied to an interior thereof,

wherein the secondary combustion chamber comprises a secondary burner configured to heat an interior thereof and ignite a combustion gas discharged from the primary combustion chamber, and a secondary air supply port configured to supply combustion air to an interior thereof,

a primary air supply device configured to supply air to the primary air supply port and the bottom portion air supply port, an injection air supply device configured to supply air to the bottom portion air injection nozzle, and a secondary air supply device configured to supply air to the secondary air supply port, and

a controller configured to control operation of the fuel supply device, the ignition burner, the secondary burner, the primary air supply device, the injection air supply device, and the secondary air supply device,

wherein the controller is configured to

accumulate a predetermined amount of the powder fuel in the primary combustion chamber by the fuel supply device,

ignite the powder fuel being accumulated using the ignition burner and activate the secondary burner to heat the interior of the secondary combustion chamber,

upon performing gasification combustion of the powder fuel being accumulated, activate the primary air supply device and the injection air supply device to supply an amount of air that is smaller than an amount of air necessary for complete combustion of the powder fuel being accumulated through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle to generate flammable gas inside the primary combustion chamber,

upon performing direct combustion of the powder fuel being accumulated, activate the primary air supply device and the injection air supply device to supply an amount of air necessary for direct combustion of the powder fuel into the primary combustion chamber through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle, and activate the fuel supply device to supply the

powder fuel into the primary combustion chamber to combust the powder fuel and activate the fuel supply device as a burner, and

upon performing gasification combustion of the powder fuel being accumulated and performing direct combustion of the powder fuel being accumulated, activate the secondary air supply device to supply an amount of secondary combustion air necessary for complete combustion of the flammable gas through the secondary air supply port to combust the flammable gas.

2. The powder fuel combustion apparatus according to claim 1,

wherein, upon performing ember combustion and ashing of the powder fuel in the primary combustion chamber, supply of fuel by the fuel supply device is stopped, and supply of air from the bottom portion air injection nozzle is also stopped.

3. The powder fuel combustion apparatus according to claim 1 or 2,

wherein, upon performing gasification combustion of the powder fuel being accumulated and upon performing direct combustion of the powder fuel being accumulated, the controller is configured to control the injection air supply device so as to inject air by an amount of injection capable of agitating the powder fuel either regularly or irregularly through the bottom portion air injection nozzle.

4. The powder fuel combustion apparatus according to any one of claims 1 through 3,

wherein the fuel supply device comprises a fuel hopper through which the powder fuel is loaded, a hopper injection nozzle arranged in a vertical direction in the fuel hopper to inject air at least to a lower direction thereof, a hopper air supply device configured to supply air to the hopper injection nozzle, a fuel delivery device arranged at a lower direction of the hopper injection nozzle and delivering the powder fuel to the lower direction, a mixing pipe in which the powder fuel and air are mixed, and a fuel blower configured to supply air to the mixing pipe, and

upon supplying the powder fuel to the primary combustion chamber, the controller is configured to activate the fuel blower and also activate the fuel delivery device, mix the powder fuel and air supplied from the fuel blower in an interior of the mixing pipe and supply the powder fuel from the mixing pipe to the primary combustion chamber, and activate the hopper air supply device at a predetermined timing to inject air through the hopper injection nozzle.

5. A combustion method of combusting a powder fuel by a powder fuel combustion apparatus, comprising:

a fuel charging step, an igniting step, a gasification combustion step, a direct combustion step, and an ember-ashing step,

wherein the powder fuel combustion apparatus comprises a primary combustion chamber configured to combust the powder fuel in an interior thereof, and a secondary combustion chamber configured to combust a gas discharged from the primary combustion chamber,

wherein the primary combustion chamber comprises a fuel supply device configured to supply the powder fuel to an interior thereof, a primary air supply port con-

figured to supply air to an interior thereof, and an ignition burner configured to ignite the powder fuel in an interior thereof,

wherein a bottom portion of the primary combustion chamber comprises an inclined portion inclined to narrow toward a lower direction, a bottom portion air supply port configured to supply air to an interior thereof, an ash outlet provided to a lower position of the inclined portion, and a bottom portion air injection nozzle having a tubular shape and arranged in a vertical direction, the bottom portion air injection nozzle comprising openings formed on an upper end and a lower end thereof, the lower end positioned toward the ash outlet, and having air supplied to an interior thereof,

wherein the secondary combustion chamber comprises a secondary burner configured to heat an interior thereof, and a secondary air supply port configured to supply combustion air to an interior thereof,

a primary air supply device configured to supply air to the primary air supply port and the bottom portion air supply port, an injection air supply device configured to supply air to the bottom portion air injection nozzle, and a secondary air supply device configured to supply air to the secondary air supply port, and

a controller configured to control operation of the fuel supply device, the ignition burner, the secondary burner, the primary air supply device, the injection air supply device, and the secondary air supply device,

wherein the controller is configured to

accumulate a predetermined amount of the powder fuel to the primary combustion chamber by the fuel supply device in the fuel charging step,

heat the interior of the secondary combustion chamber by the secondary burner, and after the interior of the secondary combustion chamber has reached a predetermined temperature, ignite the powder fuel being accumulated using the ignition burner in the igniting step,

supply an amount of air that is smaller than an amount of air necessary for complete combustion of the powder fuel being accumulated through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle to generate flammable gas in the primary combustion chamber, introduce the flammable gas to the secondary combustion chamber, and perform complete combustion of the flammable gas by supplying air for secondary combustion through the secondary air supply port in the gasification combustion step,

activate the primary air supply device and the injection air supply device to supply an amount of air necessary for direct combustion of the powder fuel into the primary combustion chamber through the primary air supply port, the bottom portion air supply port, and the bottom portion air injection nozzle, activate the fuel supply device to supply the powder fuel into the primary combustion chamber and perform combustion of the powder fuel to activate the fuel supply device as a burner, introduce combustion gas discharged from the primary combustion chamber to the secondary combustion chamber, and perform complete combustion of the combustion gas by supplying air for secondary combustion through the secondary air supply port in the direct combustion step, and

stop supply of fuel by the fuel supply device and perform ember combustion and ashing of the powder fuel remaining in the primary combustion chamber in the ember-ashing step.

6. The powder fuel combustion method according to claim 5,

wherein, in the ember-ashing step, supply of air from the bottom portion air injection nozzle is stopped.

7. The powder fuel combustion method according to 5 or 6,

wherein, in the gasification combustion step and the direct combustion step, the controller is configured to control the injection air supply device so that air is injected by an amount of injection capable of agitating the powder fuel to the bottom portion air injection nozzle either regularly or irregularly.

8. The powder fuel combustion method according to any one of claims 5 to 7,

wherein the fuel supply device comprises a fuel hopper through which the powder fuel is loaded, a hopper

injection nozzle arranged in a vertical direction in the fuel hopper to inject air at least to a lower direction thereof, a hopper air supply device configured to supply air to the hopper injection nozzle, a fuel delivery device arranged at a lower direction of the hopper injection nozzle and delivering the powder fuel to the lower direction, a mixing pipe in which the powder fuel and air are mixed, and a fuel blower configured to supply air to the mixing pipe, and

in the fuel charging step and the direct combustion step, the controller is configured to activate the fuel blower and also activate the fuel delivery device, mix the powder fuel and air supplied from the fuel blower in an interior of the mixing pipe and supply the powder fuel from the mixing pipe to the primary combustion chamber, and activate the hopper air supply device at a predetermined timing to inject air through the hopper injection nozzle.

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