

ASH REMOVAL SYSTEM

TECHNICAL FIELD

[0001] The present disclosure relates to an ash removal system. The present application
5 claims priority based on Japanese Patent Application No. 2022-016261 filed on February 4, 2022, with the Japanese Patent Office, the contents of which are incorporated herein by reference.

BACKGROUND ART

10 [0002] Ash accumulates on a heat transfer tube group of a boiler. Thus, in some cases, a boiler is provided with an ash removal system for removing ash to suppress deterioration of the heat transfer performance of the heat transfer tube group.

[0003] As an ash removal system, a method using a soot blower and a method using a pressure wave (shock pulse) are known, for instance. The method using a pressure wave can
15 be used more frequently than the typical soot blowers, and the operation control of the pressure wave is critical.

[0004] Patent Document 1 and Patent Document 2 disclose providing a pressure wave generation device for a waste incinerator at the upstream side of the heat transfer bank or in the radiation chamber, and controlling the pressure wave generation device using the pressure
20 difference between the incinerator internal pressure and the boiler outlet pressure or the gas temperature difference at the inlet of the heat transfer bank as a control factor.

Citation List

Patent Literature

25 [0005]

Patent Document 1: JP2017-181007A

Patent Document 2: JP2017-187267A

SUMMARY

[0006] With the operation control according to Patent Document 1 and Patent Document 2, it is difficult to determine the local accumulation state of ash, such as in which part of the boiler the accumulation amount of ash has increased. Furthermore, since the position of discharge of the pressure wave is fixed, the position with a high ash removal effect and the position with a low ash removal effect are fixed, which may lead to unevenness in the accumulation amount of ash. Thus, the ash removal effect is insufficient at the position where the accumulation amount of ash is relatively high and the position remote from where the pressure wave is discharged, which may lead to blockage of the gap between the heat transfer tubes and significant deterioration of the heat transfer efficiency of the boiler.

[0007] In view of the above, an object of at least one embodiment of the present disclosure is to suppress unevenness in the accumulation state of ash at a plurality of positions inside the boiler, and suppress deterioration of the heat transfer efficiency of the boiler.

[0008] To achieve the above object, an ash removal system according to at least one embodiment of the present disclosure is an ash removal system for removing ash which accumulates on a heat transfer tube group of a boiler, and includes: at least one pressure wave generation device for generating a pressure wave; at least one movable nozzle configured to be capable of moving inside the boiler, for discharging the pressure wave generated by the at least one pressure wave generation device; a monitoring device for monitoring an accumulation state of ash which accumulates on a heat transfer tube of the heat transfer tube group at each of a plurality of positions inside the boiler; and a control device configured to control at least one of a position or an orientation of a tip of each of the at least one movable nozzle on the basis of the accumulation state monitored by the monitoring device.

[0009] According to at least one embodiment of the present disclosure, provided is an ash removal system capable of suppressing unevenness in the accumulation state of ash at a plurality of positions inside the boiler, and suppress deterioration of the heat transfer efficiency of the boiler.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a schematic configuration diagram of a boiler system 2 according to an embodiment.

FIG. 2 is a cross-sectional view showing the schematic configuration of a water wall 26
5 (or 27).

FIG. 3 is a diagram showing the method of monitoring the accumulation state of ash using a camera 51 and a scale 52.

FIG. 4 is a diagram showing the method of monitoring the accumulation state of ash using a laser displacement-measuring device 55.

10 FIG. 5 is a diagram showing the method of monitoring the accumulation state of ash using an optical fiber thermometer 56.

FIG. 6 is a diagram showing an example of a hardware configuration of the control device 42 depicted in FIG. 1.

15 FIG. 7 is a block diagram showing an example of a functional configuration of the control device 42.

FIG. 8 is a diagram showing an example of a control flow of ash removal by the control device 42.

FIG. 9 is a diagram of a case where the pressure wave is discharged while orienting the tip of a movable nozzle 38 toward the middle in the flow passage width direction of the convection heat transfer chamber, showing how ash falls and accumulates on a heat transfer tube 32 below.
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FIG. 10 is a diagram of a case where the pressure wave is discharged while orienting the tip of a movable nozzle 38 toward the wall in the flow passage width direction of the convection heat transfer chamber, showing how accumulation on a heat transfer tube 32 below is suppressed.
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FIG. 11 is a diagram for showing an example of an orientation of the tip of the movable nozzle 38.

FIG. 12 is a schematic configuration diagram of a boiler system 2 according to another

embodiment.

FIG. 13 is a diagram showing an example of a control flow by the control device 42 depicted in FIG. 12.

FIG. 14 is a schematic diagram showing a movable platform 67 carrying a pressure
5 wave generation device.

FIG. 15 is a diagram showing an example of arrangement of the scale 52 on a heat transfer tube 32 with fins 64.

FIG. 16 is a diagram showing an example of usage of the laser displacement-measuring device 55 on a heat transfer tube 32 with fins 64.

10 FIG. 17 is a diagram showing an example of arrangement of the optical fiber thermometer 56 on the heat transfer tube 32 with fins 64.

DETAILED DESCRIPTION

[0011] Embodiments of the present invention will now be described in detail with
15 reference to the accompanying drawings. It is intended, however, that unless particularly identified, dimensions, materials, shapes, relative positions and the like of components described in the embodiments shall be interpreted as illustrative only and not intended to limit the scope of the present invention.

For instance, an expression of relative or absolute arrangement such as “in a direction”,
20 “along a direction”, “parallel”, “orthogonal”, “centered”, “concentric” and “coaxial” shall not be construed as indicating only the arrangement in a strict literal sense, but also includes a state where the arrangement is relatively displaced by a tolerance, or by an angle or a distance whereby it is possible to achieve the same function.

For instance, an expression of an equal state such as “same” “equal” and “uniform”
25 shall not be construed as indicating only the state in which the feature is strictly equal, but also includes a state in which there is a tolerance or a difference that can still achieve the same function.

Further, for instance, an expression of a shape such as a rectangular shape or a

cylindrical shape shall not be construed as only the geometrically strict shape, but also includes a shape with unevenness or chamfered corners within the range in which the same effect can be achieved.

On the other hand, an expression such as “comprise”, “include”, “have”, “contain” and “constitute” are not intended to be exclusive of other components.

[0012] FIG. 1 is a schematic configuration diagram of a boiler system 2 according to an embodiment.

The boiler system 2 includes a boiler 4 and an ash removal system 6. In the exemplary embodiment depicted in the drawings, the boiler 4 includes a stoker-type incinerator 8 (stoker incinerator), and an exhaust gas line 9 through which exhaust gas discharged from the incinerator 8 (exhaust gas generated from combustion of waste in the incinerator 8) flows through. The exhaust gas line 9 includes a first radiation chamber 10, a second radiation chamber 12, and a convection heat transfer chamber 14.

[0013] The incinerator 8 is configured to combust waste received from a waste receiving inlet 16 while moving the waste on the stoker 18 (fire grate), and discharge the waste from a waste discharge outlet 20.

[0014] The upper part of the incinerator 8 is connected to the lower part of the first radiation chamber 10, and the first radiation chamber 10 extends along the vertical direction, for instance, so as to guide the exhaust gas discharged from the incinerator 8 upward. The wall surface of the first radiation chamber 10 is constituted of a water wall 26. The water wall 26 of the first radiation chamber 10 includes, as depicted in FIG. 2 for instance, a plurality of heat transfer tubes 28 (incinerator wall tubes) and a plurality of fins 29 each of which couples adjacent two of the plurality of heat transfer tubes 28.

[0015] As depicted in FIG. 1, the upper part of the first radiation chamber 10 is connected to the upper part of the second radiation chamber 12 via a direction changing part 22 for changing the direction of flow of exhaust gas from upward to downward. The second radiation chamber 12 extends along the vertical direction so as to guide exhaust gas downward. The wall surface of the second radiation chamber 12 is constituted of a water

wall 27. The water wall 27 of the second radiation chamber 12 includes, as depicted in FIG. 2 for instance, a plurality of heat transfer tubes 28 (incinerator wall tubes) and a plurality of fins 29 each of which couples adjacent two of the plurality of heat transfer tubes 28.

[0016] The lower part of the second radiation chamber 12 is connected to the convection heat transfer chamber 14 via a direction changing part 24 for changing the direction of flow of exhaust gas from downward to upward. The convection heat transfer chamber 14 extends along the vertical direction so as to guide exhaust gas upward. A plurality of heat transfer banks 30 are disposed at intervals in the vertical direction inside the convection heat transfer chamber 14. The plurality of heat transfer banks 30 may include a superheater and an economizer, for instance. Each of the plurality of heat transfer banks 30 is constituted of a heat exchanger including a plurality of heat transfer tubes 32 arranged in the horizontal direction provided in multiple stages in the vertical direction.

[0017] In the above configuration, exhaust gas discharged from the incinerator 8 ascends inside the first radiation chamber 10 while exchanging heat with the water wall 26 of the first radiation chamber 10, and flows into the second radiation chamber 12 via the direction changing part 22 from the upper part of the first radiation chamber 10. The exhaust gas having flown into the second radiation chamber 12 descends inside the second radiation chamber 12 while exchanging heat with the water wall 27 of the second radiation chamber 12, and flows into the convection heat transfer chamber 14 via the direction changing part 24 from the lower part of the second radiation chamber 12. The exhaust gas having flown into the convection heat transfer chamber 14 ascends inside the convection heat transfer chamber 14 while exchanging heat with each of the plurality of heat transfer banks 30, and flows toward the further downstream side of the exhaust gas line 9 from the upper part of the convection heat transfer chamber 14.

[0018] In the above configuration, the plurality of heat transfer tubes 28 constituting the water wall 26 of the first radiation chamber 10, the plurality of heat transfer tubes 28 constituting the water wall 27 of the second radiation chamber 12, and the plurality of heat transfer tubes 32 constituting each of the plurality of heat transfer banks 30 constitute a heat

transfer tube group 35 of the boiler 4.

[0019] As depicted in FIG. 1, the ash removal system 6 includes a plurality of pressure wave generation devices 36 for generating a pressure wave (shock pulse), a plurality of movable nozzles 38 for discharging the pressure wave generated by each of the plurality of pressure wave generation devices, a monitoring device 40 for monitoring the accumulation state of ash accumulating on the heat transfer tubes (the heat transfer tubes 28 of the water wall 26, the heat transfer tubes 28 of the water wall 27, and the heat transfer tubes 32 of the heat transfer banks 30) of the heat transfer tube group 35 at each of the plurality of positions inside the boiler 4, and a control device 42.

[0020] In the illustrated embodiment, the plurality of pressure wave generation devices 36 include a pressure wave generation device 36A disposed above the boiler 4 and a pressure wave generation device 36B disposed below the boiler 4. Specifically, the pressure wave generation device 36A is disposed above the first radiation chamber 10, on the vertical line passing through the first radiation chamber 10. The pressure wave generation device 36B is disposed below the second radiation chamber 12, on the vertical line passing through the second radiation chamber 12. Furthermore, the distance between the pressure wave generation device 36A and the first radiation chamber 10 is smaller than the distance between the pressure wave generation device 36A and the convection heat transfer chamber 14, and the pressure wave generation device 36A is disposed closer to the first radiation chamber 10 than to the convection heat transfer chamber 14. Furthermore, the distance between the pressure wave generation device 36B and the second radiation chamber 12 is smaller than the distance between the pressure wave generation device 36B and the convection heat transfer chamber 14, and the pressure wave generation device 36B is disposed closer to the second radiation chamber 12 than to the convection heat transfer chamber 14.

[0021] A plurality of movable nozzles 38 include a plurality of movable nozzles 38A for discharging the pressure wave generated by the pressure wave generation device 36A and a plurality of movable nozzles 38B for discharging the pressure wave generated by the pressure wave generation device 36B.

[0022] The plurality of movable nozzles 38A include a movable nozzle 38A1 corresponding to the first radiation chamber 10 and disposed so as to be capable of discharging the pressure wave into the first radiation chamber 10, a movable nozzle 38A2 corresponding to the upper part of the second radiation chamber 12 and disposed so as to be capable of discharging the pressure wave into the upper part of the second radiation chamber 12, and a movable nozzle 38A3 corresponding to the upper part of the convection heat transfer chamber 14 and disposed so as to be capable of discharging the pressure wave into the upper part of the convection heat transfer chamber 14. The plurality of movable nozzles 38B include a movable nozzle 38B1 corresponding to the lower part of the second radiation chamber 12 and disposed so as to be capable of discharging the pressure wave into the lower part of the second radiation chamber 12, and a movable nozzle 38B2 corresponding to the lower part of the convection heat transfer chamber 14 and disposed so as to be capable of discharging the pressure wave into the lower part of the convection heat transfer chamber 14. Each of the movable nozzles 38 is configured to be capable of extending and contracting, as well as changing the direction of the tip of the movable nozzle 38 (e.g., angle with respect to the vertical direction), and the tip of the movable nozzle 38 reaches the height of the floor level of each heat transfer bank 30 just by extending or contracting the movable nozzle 38.

[0023] Furthermore, in the illustrated example, the distance between the pressure wave generation device 36A and the inlet of the pressure wave of the movable nozzle 38A1 (root end of the movable nozzle 38A1) is smaller than the distance between the pressure wave generation device 36A and the inlet of the pressure wave of the movable nozzle 38A3 (root end of the movable nozzle 38A3). Furthermore, the distance between the pressure wave generation device 36B and the inlet of the pressure wave of the movable nozzle 38B1 (root end of the movable nozzle 38B1) is smaller than the distance between the pressure wave generation device 36B and the inlet of the movable nozzle 38B2 (root end of the movable nozzle 38B2).

[0024] In the illustrated embodiment, the ash removal system 6 includes a first pipe part 44A which connects to the pressure wave generation device 36A and through which the

pressure wave generated by the pressure wave generation device 36A passes, and a plurality of second pipe parts 45A1 to 45A3 each connecting the first pipe part 44A and corresponding one of the plurality of movable nozzles 38A1 to 38A3. Furthermore, the ash removal system 6 includes a valve 46A1 disposed in the first pipe part 44A between the connection position to the second pipe part 45A1 and the connection position to the second pipe part 45A2, and a valve 46A2 disposed in the first pipe part 44A between the connection position to the second pipe part 45A2 and the connection position to the second pipe part 45A3, and a plurality of valves 47A1 to 47A3 disposed in the plurality of second pipe parts 45A1 to 45A3, respectively. The valve 47A1 is disposed in the second pipe part 45A1, the valve 47A2 is disposed on the second pipe part 45A2, and the valve 47A3 is disposed on the second pipe part 45A3.

[0025] Furthermore, in the illustrated embodiment, the ash removal system 6 includes a first pipe part 44B which connects to the pressure wave generation device 36B and through which the pressure wave generated by the pressure wave generation device 36B passes, and a plurality of second pipe parts 45B1, 45B2 each connecting the first pipe part 44A and corresponding one of the plurality of movable nozzles 38B1, 38B2. Furthermore, the ash removal system 6 includes a valve 46B1 disposed in the first pipe part 44B between the connection position to the second pipe part 45B1 and the connection position to the second pipe part 45B2, and a valve 46B2 disposed in the first pipe part 44B between the connection position to the second pipe part 45B2 and the connection position to the second pipe part 45B3, and a plurality of valves 47B1, 47B2 disposed in the plurality of second pipe parts 45B1, 45B2, respectively. The valve 47B1 is disposed in the second pipe part 45B1, and the valve 47B2 is disposed on the second pipe part 45B2.

[0026] Furthermore, in the illustrated embodiment, the monitoring device 40 includes at least one visible camera 51 (in the illustrated example, a plurality of visible cameras 51) for monitoring the accumulation state of ash which accumulates on the heat transfer tube (the heat transfer tube 28 of the water wall 26, the heat transfer tube 28 of the water wall 27, and the heat transfer tube 32 of the heat transfer bank 30) of the heat transfer tube group 35 at

each of the plurality of positions inside the boiler 4. In this case, the monitoring device 40 may include a plurality of visible cameras 51 for monitoring the accumulation state of ash at each of the plurality of positions inside the boiler 4, and a plurality of scales 52 (see FIG. 3) disposed at the plurality of corresponding positions inside the boiler 4. The scale 52 may be an ash adhesion detection plate having a length that serves as a reference for measuring the accumulation thickness of ash, or a scale that has marks, for instance.

[0027] In the example depicted in FIG. 3, each of the plurality of scales 52 is fixed on the heat transfer tube (heat transfer tube 32 in the example depicted in FIG. 3) constituting the heat transfer tube group 35, so as to stand upright along the accumulating direction of ash.

The plurality of scales 52 may include, as depicted in FIG. 3, a plurality of scales 52 having different heights from one another at different positions in the longitudinal direction of the heat transfer tube (extending direction of the heat transfer tube). In the configuration depicted in FIG. 3, the visible camera 51 captures an image including the scale 52 and ash accumulating in the vicinity of the scale 52 through a inspection window 53 of the boiler 4, and thereby it is possible to monitor whether the accumulation thickness of ash at the position of the scale 52 is not smaller than the threshold value. Furthermore, as depicted in FIG. 3, the above image maybe captured while illuminating the scale 52 with light from a light source 54.

[0028] It should be noted that the configuration of the monitoring device 40 is not limited to the above, and the monitoring device 40 may include, as depicted in FIG. 4, at least one laser displacement-measuring device 55 for monitoring the accumulation state of ash which accumulates on the heat transfer tube (the heat transfer tube 28 of the water wall 26, the heat transfer tube 28 of the water wall 27, and the heat transfer tube 32 of the heat transfer bank 30) of the heat transfer tube group 35 at each of the plurality of positions inside the boiler 4.

In the example depicted in FIG. 4, the laser displacement-measuring device 55 emits a laser along the longitudinal direction of the heat transfer tube 32 at a predetermined height from the heat transfer tube 32, and the laser displacement-measuring device 55 receives the reflected laser from the ash, whereby it is possible to monitor whether the accumulation thickness of

ash accumulating on the heat transfer tube 32 is not smaller than the threshold value, and it is possible to determine the position where the accumulation thickness of ash is not smaller than the threshold value. In this case, the monitoring device 40 may include a plurality of laser displacement-measuring devices 55 for monitoring the accumulation state of ash at each of the plurality of positions inside the boiler 4.

[0029] Furthermore, as depicted in FIG. 5 for instance, the monitoring device 40 may include at least one optical fiber thermometer 56 for monitoring the accumulation state of ash at a plurality of positions of the heat transfer tube group 35. In the example illustrated in FIG. 5, the optical fiber thermometer 56 is disposed on the surface of a heat transfer tube 32 along the longitudinal direction of the heat transfer tube 32. Accordingly, the optical fiber thermometer 56 is capable of measuring the temperature of each position in the longitudinal position of the heat transfer tube 32. During operation of the boiler 4, the temperature of each position in the longitudinal direction of the heat transfer tube 32 changes depending on the accumulation state of ash at the position, and the position with a larger accumulation thickness of ash has a lower temperature. Thus, by measuring the temperature of each position in the longitudinal direction of the heat transfer tube 32 with the optical fiber thermometer 56 and monitoring whether the temperature of each position in the longitudinal direction of the heat transfer tube 32 is not lower than the threshold value, it is possible to determine the accumulation state of ash at each position in the longitudinal direction of the heat transfer tube 32.

[0030] FIG. 6 is a diagram showing an example of a hardware configuration of the control device 42 depicted in FIG. 1. FIG. 7 is a block diagram showing an example of a functional configuration of the control device 42. FIG. 8 is a diagram showing an example of a control flow of ash removal by the control device 42.

[0031] As depicted in FIG. 6, the control device 42 is configured with a computer constituted of a processor 72, a Random Access Memory (RAM) 74, a Read Only Memory (ROM) 76, a Hard Disk Drive (HDD) 78, an input I/F 80, and an output I/F 82, which are connected to one another via a bus 84. The hardware configuration of the control device 42

is not limited to the above, and may be configured with a combination of a control circuit and a storage device. The control device 42 is configured by a computer implementing a program for realizing each function of the control device 42. The function of each part of the control device 42 described below is realized by, for instance, loading the program stored in the ROM 76 and executing the same with the processor 72, while reading and writing data with the RAM 76 and the ROM 76.

[0032] As depicted in FIG. 7, the control device 42 includes a pressure wave path control part 60, a movable nozzle control part 61, and a pressure wave control part 62.

[0033] As depicted in FIG. 8, in S101, the monitoring device 40 monitors the accumulation state of ash accumulating on the heat transfer tube (the heat transfer tube 28 of the water wall 26, the heat transfer tube 28 of the water wall 27, and the heat transfer tube 32 of the heat transfer bank 30) of the heat transfer tube group 35.

[0034] In S102, at each of the plurality of positions of the boiler 4 monitored in S101, it is determined whether the parameter related to the accumulation state of ash is not smaller than the threshold value. Herein, the parameter related to the accumulation state of ash may be the accumulation thickness of ash measured as described above by the visible camera 51 or the laser displacement-measuring device 55 in a case where the monitoring device 40 includes the visible camera 51 or the laser displacement-measuring device 55, or the temperature measured as described by the optical fiber thermometer 56 in a case where the monitoring device 40 includes the optical fiber thermometer 56.

[0035] In S102, at each of the plurality of positions of the boiler 4 monitored in S101, if it is determined that the parameter related to the accumulation state of ash is smaller than the threshold value, the process returns to S101 and the monitoring device 40 continues to monitor the accumulation state of ash.

[0036] In S102, if the parameter related to the accumulation state of ash is not smaller than the threshold value with regard to at least one of the plurality of positions inside the boiler 4 monitored in S101, the pressure wave path control part 60 controls, in S103, the valves 46A1, 46A2, 47A1 to 47A3, 46B1, 47B1, 47B2 so as to send a pressure wave to a

movable nozzle 38 corresponding to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value (preferably, the movable nozzle 38 closest to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value).

5 [0037] If the parameter related to the accumulation state of ash is not smaller than the threshold value at a position inside the first radiation chamber 10, for instance in FIG. 1, the pressure wave path control part 60 opens the valve 47A1 corresponding to the movable nozzle 38A1, and closes the other valves 46A1, 46A2, 47A2, 47A3, 46B1, 47B1, and 47B2.

[0038] If the parameter related to the accumulation state of ash is not smaller than the
10 threshold value at a position inside the upper part of the second radiation chamber 12, for instance in FIG. 1, the pressure wave path control part 60 opens the valves 46A1, 47A2 corresponding to the movable nozzle 38A2, and closes the other valves 46A2, 47A1, 47A3, 46B1, 47B1, and 47B2.

[0039] If the parameter related to the accumulation state of ash is not smaller than the
15 threshold value at a position inside the lower part of the second radiation chamber 12, for instance in FIG. 1, the pressure wave path control part 60 opens the valve 47B1 corresponding to the movable nozzle 38B1, and closes the other valves 46A1, 46A2, 47A1 to 47A3, 46B1, and 47B2.

[0040] If the parameter related to the accumulation state of ash is not smaller than the
20 threshold value at a position inside the upper part of the convection heat transfer chamber 14, for instance in FIG. 1, the pressure wave path control part 60 opens the valves 46A1, 46A2, 47A3 corresponding to the movable nozzle 38A3, and closes the other valves 47A1, 47A2, 46B1, 47B1, and 47B2.

[0041] If the parameter related to the accumulation state of ash is not smaller than the
25 threshold value at a position inside the lower part of the convection heat transfer chamber 14, for instance in FIG. 1, the pressure wave path control part 60 opens the valves 46B1, 47B2 corresponding to the movable nozzle 38B2, and closes the other valves 46A1, 46A2, 47A1 to 47A3, and 47B1.

[0042] In S104, the movable nozzle control part 61 moves the tip of the movable nozzle 38 corresponding to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value (preferably, the movable nozzle 38 closest to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value) toward the position where the parameter related to the accumulation state of ash is not smaller than the threshold value. The movable nozzle control part 61 moves the tip of the movable nozzle 38 corresponding to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value to the vicinity of the position where the parameter related to the accumulation state of ash is not smaller than the threshold value, and adjusts the position and the orientation of the tip of the movable nozzle 38 such that the tip of the nozzle 38 is oriented toward the position. It should be noted that the tip of the movable nozzle 38 refers to the outlet of the pressure wave of the movable nozzle 38, that is, the nozzle port of the movable nozzle 38 that discharges the pressure wave. Furthermore, the vicinity of the position where the parameter related to the accumulation state of ash refers to a range close enough to the position so that it is possible to remove at least a part of the ash at the position by discharging the pressure wave.

[0043] In S104, hypothetically, if the pressure wave is discharged with the tip of the movable nozzle 38 oriented toward the middle in the flow passage width direction of the convection heat transfer chamber as depicted in FIG. 9, ash separated from the heat transfer tube 32 accumulates on the heat transfer tube 32 at the lower side in the gravity direction, where the ash may start developing and close the gap of the heat transfer tubes 32. Thus, in S104, as depicted in FIG. 10, by controlling the position and the direction of the tip of the movable nozzle 38 so as to discharge the pressure wave toward the wall in the flow passage width direction of the convection heat transfer chamber 14, separated ash falls through the gap between the heat transfer bank 30 and the wall of the convection heat transfer chamber, and thus it is possible to suppress blockage of the gap of the heat transfer tube 32 described above.

[0044] Furthermore, as depicted in FIG. 11, in a case where the plurality of fins 64 are disposed on the heat transfer tube 32 along the flow direction of exhaust gas so as to intersect

with the heat transfer tube 32, the movable nozzle control part 61 may control the position and the direction of the movable nozzle 38 such that the tip of the movable nozzle 38 is oriented in the direction intersecting (preferably, orthogonally) with each of the longitudinal direction of the heat transfer tube 32 and the flow direction of exhaust gas.

5 [0045] In a case where the heat transfer tube 32 has fins, it is important to ensure the heat transfer area in addition to prevention of clogging. Thus, by discharging the pressure wave while orienting the tip of the movable nozzle 38 in the direction intersecting with each of the longitudinal direction of the heat transfer tube 32 and the flow direction of exhaust gas so as to remove ash accumulating in the flow direction of exhaust gas (ash accumulating over fins
10 arranged adjacently in the flow direction of exhaust gas, in particular) as well as ash accumulating in the flow passage width direction, it is possible to remove ash accumulating in the flow direction of exhaust gas and maintain the heat transfer area.

[0046] In S105, the pressure wave control part 62 generates a pressure wave from the pressure wave generation device 36 connecting to the movable nozzle 38 moved in S104, and
15 discharges the pressure wave from the movable nozzle 38. The pressure wave control part 62 operates the pressure wave generation device 36A if the movable nozzles 38A1 to 38A3 in FIG. 1 are to be used, and operates the pressure wave generation device 36B if the movable nozzle 38B1, 38B2 in FIG. 1 are to be used. The pressure wave control part 62 may perform a control to, for instance, enhance the pressure wave generated from the pressure wave
20 generation device 36, and/or increase the generation frequency of the pressure wave, as the position where the parameter related to the accumulation state of ash is not smaller than the threshold value approaches the upstream side in the flow direction of exhaust gas.

[0047] In S106, it is determined again whether the parameter related to the accumulation state of ash is smaller than the threshold value using the monitoring device 40. If it is
25 determined that the parameter related to the accumulation state of ash is not smaller than the threshold value in S106, the step S105 is executed again. If it is determined that the parameter related to the accumulation state of ash is smaller than the threshold value in S106, in S107, the pressure wave control part 62 determines that the ash at the target position is

appropriately removed and stops operation of the pressure wave generation device 36, and the movable nozzle control part 61 retracts the movable nozzle 38 that has discharged the pressure wave in S105.

[0048] Furthermore, the above control flow may include, after S106, learning by machine

5 learning the relationship between the discharge pattern of the pressure wave (operation method of shock pulse) in S104 and S105 and the case where the parameter related to the accumulation state of ash is determined to be smaller than the threshold value in S106, on the basis of the determination result in S106, and using the result of learning as a feedback for the discharge pattern of the pressure wave in S104 and S105. The discharge pattern of the

10 pressure wave here may include at least one of the generation frequency of the pressure wave, the strength of the pressure wave and the orientation of the tip of the movable nozzle 38 that discharges the pressure wave (direction of discharging the pressure wave), or all of the above.

Furthermore, the threshold value used in S102 and S106 may be changed on the basis of the learning result of the above machine learning. Furthermore, in a case where the
15 accumulation thickness of ash is measured at each position of the heat transfer tube by using the optical fiber thermometer 56 or the like, the accumulation thickness of ash measured by the optical fiber thermometer 56 and the position corresponding to the accumulation thickness may be included in the parameter to be learned in the machine learning.

[0049] According to the ash removal system 6, by controlling the position and the

20 orientation of the tip of each of the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2 on the basis of the accumulation state of ash on the heat transfer tube (the heat transfer tube 28 of the water wall 26, the heat transfer tube 28 of the water wall 27, and the heat transfer tube 32 of the heat transfer tube 30) at each of the plurality of positions inside the boiler 4, it is possible to remove ash efficiently on the basis of the accumulation state of ash on the heat
25 transfer tube at each of the plurality of positions inside the boiler 4. Accordingly, it is possible to suppress unevenness in the accumulation state of ash at a plurality of positions inside the boiler 4, and suppress deterioration of the heat transfer efficiency of the boiler 4. Furthermore, it is possible to discharge the pressure wave to an appropriate position by

controlling the position and the orientation of the tip of each of the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2, and thus it is possible to suppress an increase in the number of the pressure wave generation devices 63.

[0050] Furthermore, in a case where the incinerator 8 is of a stoker type, the fuel to be used contains a high amount of alkali metal and heavy metal, and thus the sintering rate of ash is higher and the melting point is lower than the case of a coal type. Therefore, ash is more likely to adhere and melt on the heat transfer tube 28 of the heat transfer bank 30 and the heat transfer tubes 28 of the water walls 26, 27 inside the boiler 4 compared to a coal boiler. Thus, in a case where the incinerator 8 is of a stoker type, the above ash removal system 6 capable of removing ash efficiently is preferably applicable.

[0051] Furthermore, it is possible to select a movable nozzle 38 that discharges the pressure wave from among the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2 through opening and closing of the valves 46A1, 46A2, 46B1, 46B2, 47A1, 47A2, 47A3, 47B1, 47B2. Thus, it is possible to select an appropriate movable nozzle 38 from among the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2 with a simple configuration and discharge the pressure wave.

[0052] Furthermore, the adhesion force of ash inside the boiler 4 tends to increase toward the high-temperature side, that is, the upstream side, inside the boiler 4. Thus, by setting the distance between the pressure wave generation device 36A and the inlet of the pressure wave of the movable nozzle 38A1 to be smaller than the distance between the pressure wave generation device 36A and the inlet of the pressure wave of the movable nozzle 38A3, it is possible to reduce attenuation of the pressure wave between the pressure wave generation device 36A and the movable nozzle 38A1 to be smaller than attenuation of the pressure wave between the pressure wave generation device 36A and the movable nozzle 38A3. Accordingly, it is possible to enhance the pressure wave discharged from the movable nozzle 38A1 corresponding to the high-temperature side (upstream side) inside the boiler 4 to be stronger than the pressure wave discharged from the movable nozzle 38A3 corresponding to the low-temperature side (downstream side) inside the boiler 4, and it is possible to remove

ash inside the boiler 4 efficiently depending on the adhesion force.

[0053] Furthermore, for the same reason, by setting the distance between the pressure wave generation device 36B and the inlet of the pressure wave of the movable nozzle 38B1 to be smaller than the distance between the pressure wave generation device 36B and the inlet of the pressure wave of the movable nozzle 38B2, it is possible to efficiently remove ash adhering to the heat transfer tube inside the boiler 4 in accordance with the adhesion force. Furthermore, for the same reason, by setting the distance between the pressure wave generation device 36A and the first radiation chamber 10 to be smaller than the distance between the pressure wave generation device 36A and the convection heat transfer chamber 14, it is possible to efficiently remove ash adhering to the heat transfer tube inside the boiler 4 in accordance with the adhesion force. Furthermore, for the same reason, by setting the distance between the pressure wave generation device 36B and the second radiation chamber 12 to be smaller than the distance between the pressure wave generation device 36B and the convection heat transfer chamber 14, it is possible to efficiently remove ash adhering to the heat transfer tube inside the boiler 4 in accordance with the adhesion force.

[0054] Furthermore, by discharging the pressure wave at the position where the parameter related to the accumulation state of ash is not smaller than the threshold value, it is possible to efficiently remove ash at the position where the accumulation thickness of ash has reached a certain level, and suppress unevenness in the accumulation amount of ash at the plurality of positions inside the boiler 4, thereby suppressing deterioration of the heat transfer efficiency of the boiler 4.

[0055] Furthermore, in a case where the parameter related to the accumulation state of ash becomes smaller than the threshold value due to discharge of the pressure wave from the movable nozzle 38, it is possible to suppress excessive discharge of the pressure wave by stopping operation of the pressure wave generation device 36 that has supplied the pressure wave to the movable nozzle 38, and thus it is possible to suppress an increase in the load to the heat transfer tube, and suppress an increase in the operation cost of the pressure wave generation device 36.

[0056] FIG. 12 is a schematic configuration diagram of a boiler system 2 according to another embodiment.

In the boiler system 2 depicted in FIG. 12, reference signs that are common to respective features of the boiler system 2 depicted in FIG. 1 indicate the same features as those of the boiler system 2 depicted in FIG. 1 unless otherwise stated, and not described in detail.

[0057] The configuration depicted in FIG. 12 is different from the configuration depicted in FIG. 1 in that the ash removal system 6 includes a rail 65 for moving the pressure wave generation device 36A and a rail 66 for moving the pressure wave generation device 36B.

Furthermore, the configuration for connecting the pressure wave generation device 36A to the movable nozzles 38A1 to 38A3 and the configuration for connecting the pressure wave generation device 36B to the movable nozzles 38B1, 38B2 are different from those depicted in FIG. 1.

[0058] In the configuration depicted in FIG. 12, the pressure wave generation device 36A is configured to move on the rail 65, and is capable of docking with each of the plurality of movable nozzles 38A 1 to 38A3. The pressure wave generation device 36A is configured to switch the movable nozzle 38 (38A1, 38A2, or 38A3) to be docked among the plurality of movable nozzles 38A1 to 38A3 by moving on the rail 65.

[0059] In the configuration depicted in FIG. 12, the pressure wave generation device 36B is configured to move on the rail 66, and is capable of docking with each of the plurality of movable nozzles 38B1, 38B2. The pressure wave generation device 36B is configured to switch the movable nozzle 38 (38B1 or 38B2) to be docked among the plurality of movable nozzles 38A1, 38B2 by moving on the rail 66.

[0060] While the function of the control device 42 shown in FIG. 12 is basically similar to the configuration of the control device 42 depicted in FIGs. 6 and 7, the control flow of the control device 42 is partially different from the control flow shown in FIG. 8.

[0061] FIG. 13 is a diagram showing an example of a control flow by the control device 42 depicted in FIG. 12.

S201, S202, S204 to S207 are similar to S101, S102, S104 to S107 (including the content of the machine learning after S106) respectively, and thus not described in detail. In the control flow depicted in FIG. 2, the content of S203 is different from S103.

[0062] In S202, if the parameter related to the accumulation state of ash is not smaller than the threshold value with regard to at least one of the plurality of positions inside the boiler 4 monitored in S201, in S203, to the movable nozzle 38 corresponding to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value (preferably, the movable nozzle 38 closest to the position where the parameter related to the accumulation state of ash is not smaller than the threshold value), the pressure wave generation device 36A or 36B corresponding to the movable nozzle 38 is docked. Each of the valves 47A1 to 47A3, 47B1, 47B2 may be always open, or only the valve 47 corresponding to the movable nozzle 38 to be docked with the pressure wave generation device 36 may be opened.

[0063] If the parameter related to the accumulation state of ash is not smaller than the threshold value at a position inside the first radiation chamber 10, for instance in FIG. 12, the pressure wave path control part 60 opens the valve 47A1 corresponding to the movable nozzle 38A1, while docking the movable nozzle 38A1 to the pressure wave generation device 36A.

[0064] If the parameter related to the accumulation state of ash is not smaller than the threshold value in the upper part of the second radiation chamber 12, for instance in FIG. 12, the pressure wave path control part 60 opens the valve 47A2 corresponding to the movable nozzle 38A2, while docking the pressure wave generation device 36A to the movable nozzle 38A2.

[0065] If the parameter related to the accumulation state of ash is not smaller than the threshold value in the lower part inside the second radiation chamber 12, for instance in FIG. 1, the pressure wave path control part 60 opens the valve 47B1 corresponding to the movable nozzle 38B1, while docking the pressure wave generation device 36B to the movable nozzle 38B1.

[0066] If the parameter related to the accumulation state of ash is not smaller than the

threshold value in the upper part of the convection heat transfer chamber 14, for instance in FIG. 12, the pressure wave path control part 60 opens the valve 47A3 corresponding to the movable nozzle 38A3, while docking the pressure wave generation device 36A to the movable nozzle 38A3.

5 [0067] If the parameter related to the accumulation state of ash is not smaller than the threshold value in the lower part inside the convection heat transfer chamber 14, for instance in FIG. 12, the pressure wave path control part 60 opens the valve 47B2 corresponding to the movable nozzle 38B2, while docking the pressure wave generation device 36B to the movable nozzle 38B2.

10 [0068] According to the ash removal system 6 described above with reference to FIGs. 12 and 13, by controlling the position and the orientation of the tip of each of the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2 on the basis of the accumulation state of ash on the heat transfer tube (the heat transfer tube 28 of the water wall 26, the heat transfer tube 28 of the water wall 27, and the heat transfer tube 32 of the heat transfer tube 30) at each of the
15 plurality of positions inside the boiler 4, it is possible to remove ash efficiently on the basis of the accumulation state of ash on the heat transfer tube at each of the plurality of positions inside the boiler 4. Accordingly, it is possible to suppress unevenness of the accumulation state of ash at a plurality of positions inside the boiler 4, and suppress deterioration of the heat transfer efficiency of the boiler 4. Furthermore, it is possible to discharge the pressure wave
20 to an appropriate position by controlling the position and the orientation of the tip of each of the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2, and thus it is possible to suppress an increase in the number of the pressure wave generation devices 63.

[0069] Furthermore, by switching the movable nozzle 38 by moving the pressure wave generation device 36, it is possible to reduce the number of the pressure wave generation
25 devices 36 compared to the case where the same number of pressure wave generation devices 36 as the movable nozzles 38 are provided. Furthermore, compared to the configuration depicted in FIG. 1, the path for transmitting the pressure wave from the pressure wave generation device 36 to the movable nozzle 38 is simplified, and it is possible to reduce the

number of valves.

[0070] Embodiments of the present invention were described in detail above, but the present invention is not limited thereto, and various amendments and modifications may be implemented.

5 [0071] For instance, in each of the embodiments described above, the position and the orientation of the tip of each of the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2 are controlled on the basis of the accumulation state of ash on the heat transfer tube (the heat transfer tube 28 of the water wall 26, the heat transfer tube 28 of the water wall 27, and the heat transfer tube 32 of the heat transfer tube 30) at each of the plurality of positions inside
10 the boiler 4. Nevertheless, for instance, only either one of the position or the orientation of the tip of each of the plurality of movable nozzles 38A1 to 38A3, 38B1, 38B2 may be controlled on the basis of the accumulation state of ash on the heat transfer tube at each of the plurality of positions inside the boiler 4. That is, the present disclosure includes controlling
15 nozzles 38A1 to 38A3, 38B1, 38B on the basis of the accumulation state of ash on the heat transfer tube at each of the plurality of positions inside the boiler 4.

[0072] Furthermore, for instance, in the configuration depicted in FIG. 12, the rails 65, 66 are illustrated as an example of a moving unit for moving the pressure wave generation device 36. Nevertheless, the moving unit is not limited to the rails 65, 66, and may be a movable
20 platform 67 (a trolley carrying the pressure wave generation device 36 in the depicted example) for moving the pressure wave generation device 36 as depicted in FIG. 14, for instance. In this case, the control device 42 may execute the control flow described with reference to FIG. 13 similarly.

[0073] Furthermore, in the configuration illustrated in each of FIGs. 1 and 12, a single
25 pressure wave generation device 36 is disposed either at an upper part of a lower part of the boiler 4. Nevertheless, the pressure wave generation device 36 may be disposed at only one of the upper part or the lower part of the boiler 4, or two or more pressure wave generation devices 36 may be disposed on one or each of the upper part or the lower part of the boiler 4.

[0074] Furthermore, as depicted in FIG. 15, in a case where a plurality of fins 64 are disposed on the heat transfer tube 32 so as to intersect with the heat transfer tubes 32 (where the heat transfer tube 32 is a tube with fins), if the monitoring device 40 includes the visible camera 51 and the scale 52, the scale 52 may be disposed along the fins 64. In a case where the heat transfer tube 32 has fins, ash is expected to accumulate from the fins 64. Thus, the scale 52 may preferably be fixed to the fins 64, disposed in the vicinity of the fins 64, or may be a guideline drawn on the fins 64. Accordingly, it is possible to determine the accumulation state of ash appropriately using the scale 52 and the visible camera 51 with regard to the heat transfer tube 32 with fins where ash is likely to accumulate.

[0075] Furthermore, as depicted in FIG. 16 for instance, in a case where the plurality of fins 64 are disposed on the heat transfer tube 32 so as to intersect with the heat transfer tube 32, if the monitoring device 40 includes the laser displacement-measuring device 55, the laser displacement-measuring device 55 may be configured to emit a laser along the longitudinal direction of the heat transfer tube 32 at a position higher than the upper end 64e of the plurality of fins 64. Accordingly, it is possible to determine the accumulation state of ash appropriately using the laser displacement-measuring device 55 with regard to the heat transfer tube 32 with fins where ash is likely to accumulate.

[0076] Furthermore, as depicted in FIG. 17 for instance, in a case where the plurality of fins 64 are disposed on the heat transfer tube 32 so as to intersect with the heat transfer tube 32 and a cutout 64a is provided for each of the plurality of fins 64 on the same straight line L1, if the monitoring device 40 includes the optical fiber thermometer 56, at least a part of the optical fiber thermometer 56 may be disposed along the longitudinal direction of the heat transfer tube 32 at the position of the cutout 64a of each of the plurality of fins 64 (inside the cutout 64). Accordingly, it is possible to determine the accumulation state of ash appropriately using the optical fiber thermometer 56 with regard to the heat transfer tube 32 with fins where ash is likely to accumulate.

[0077] The contents described in the above respective embodiments can be understood as

follows, for instance.

[0078] (1) According to at least one embodiment of the present disclosure, an ash removal system (e.g., the above described ash removal system 6) is an ash removal system for removing ash which accumulates on a heat transfer tube group (e.g., the above described heat transfer tube group 35) of a boiler (e.g., the above described boiler 4), and includes: at least one pressure wave generation device (e.g., the above described pressure wave generation device 36A, 36B) for generating a pressure wave; at least one movable nozzle (e.g., the above described movable nozzles 38A1 to 38A3, 38B1, 38B2) configured to be capable of moving inside the boiler, for discharging the pressure wave generated by the at least one pressure wave generation device; a monitoring device (e.g., the above described monitoring device 40) for monitoring an accumulation state of ash which accumulates on a heat transfer tube of the heat transfer tube group at each of a plurality of positions inside the boiler; and a control device (e.g., the above described control device 42) configured to control at least one of a position or an orientation of a tip of each of the at least one movable nozzle on the basis of the accumulation state monitored by the monitoring device.

[0079] According to the ash removal system described above (1), by controlling the at least one of the position or the orientation of the tip of each of the plurality of movable nozzles on the basis of the accumulation state of ash on the heat transfer tube at each of the plurality of positions inside the boiler, it is possible to remove ash efficiently on the basis of the accumulation state of ash on the heat transfer tube at each of the plurality of positions inside the boiler. Accordingly, it is possible to suppress unevenness in the accumulation state of ash at a plurality of positions inside the boiler, and suppress deterioration of the heat transfer efficiency of the boiler. Furthermore, it is possible to discharge the pressure wave to an appropriate position by controlling the position and the orientation of the tip of each of the at least one movable nozzle, and thus it is possible to suppress an increase in the number of the pressure wave generation devices.

[0080] (2) In some embodiments, in the ash removal system described in the above (1), the at least one movable nozzle includes a plurality of movable nozzles (e.g., the above

described movable nozzles 38A1 to 38A3, 38B1, 38B2) for discharging the pressure wave generated by the at least one pressure wave generation device, and the control device is configured to control at least one of the position or the orientation of the tip of each of the plurality of movable nozzles on the basis of the accumulation state monitored by the monitoring device.

[0081] According to the ash removal system described above (2), by controlling at least one of the position or the orientation of the tip of each of the plurality of movable nozzles on the basis of the accumulation state of ash at each of the plurality of positions inside the boiler, it is possible to remove ash efficiently on the basis of the accumulation state of ash at each of the plurality of positions inside the boiler. Accordingly, it is possible to suppress unevenness in the accumulation state of ash at a plurality of positions inside the boiler, and suppress deterioration of the heat transfer efficiency of the boiler. Furthermore, it is possible to discharge the pressure wave to an appropriate position by controlling the position and the orientation of the tip of the plurality of movable nozzles, and thus it is possible to suppress an increase in the number of the pressure wave generation devices.

[0082] (3) In some embodiments, in the ash removal system described in the above (2), the at least one pressure wave generation device includes a first pressure wave generation device (e.g., the above described pressure wave generation device 36A or 36B) for generating the pressure wave, and the ash removal system includes: a first pipe part (e.g., the above described first pipe part 44A, 44B) which is connecting to the first pressure wave generation device and through which the pressure wave generated by the first pressure wave generation device passes; a plurality of second pipe parts (e.g., the above described second pipe parts 45A1 to 45A3, 45B1, 45B2) each connecting the first pipe part and corresponding one of the plurality of movable nozzles; and a valve disposed in each of the plurality of second pipes (e.g., the above described valves 46A1, 46A2, 46B1, 46B2, 47A1, 47A2, 47A3, 47B1, 47B2).

[0083] According to the ash removal system described in the above (3), it is possible to select the movable nozzle that discharges the pressure wave among the plurality of movable nozzles through opening and closing of the valves. Thus, it is possible to select an

appropriate movable nozzle from the plurality of movable nozzles with a simple configuration and discharge the pressure wave.

[0084] (4) In some embodiments, in the ash removal system described in the above (3), the plurality of movable nozzles include: a first movable nozzle (e.g., one of the plurality of movable nozzles 38 described above) configured to be capable of discharging the pressure wave into a first space inside the boiler; and a second movable nozzle (e.g., the movable nozzle 38 capable of discharging the pressure wave to the space downstream of the first movable nozzle, among the plurality of movable nozzles 38 described above) configured to be capable of discharging the pressure wave into a second space inside the boiler disposed at a downstream side of the first space, and a distance between the first pressure wave generation device and an inlet of the pressure wave of the first movable nozzle is smaller than a distance between the first pressure wave generation device and an inlet of the pressure wave of the second movable nozzle.

[0085] The adhesion force of ash inside the boiler tends to increase toward the high-temperature side, that is, the upstream side, inside the boiler. Thus, by setting the distance between the first pressure wave generation device and the inlet of the pressure wave of the first movable nozzle to be smaller than the distance between the first pressure wave generation device and the inlet of the pressure wave of the second movable nozzle as described in the above (4), it is possible to reduce attenuation of the pressure wave between the first pressure wave generation device and the first movable nozzle to be smaller than attenuation of the pressure wave between the first pressure wave generation device and the second movable nozzle. Accordingly, it is possible to enhance the pressure wave discharged from the first movable nozzle corresponding to the high-temperature side (upstream side) inside the boiler to be stronger than the pressure wave discharged from the second movable nozzle corresponding to the low-temperature side (downstream side) inside the boiler, and it is possible to remove ash having a high adhesion force at the high-temperature side inside the boiler efficiently.

[0086] (5) In some embodiments, in the ash removal system described in the above (2),

the at least one pressure wave generation device includes a first pressure wave generation device (e.g., the above described pressure wave generation device 36A or 36B) for generating the pressure wave, the ash removal system includes a moving unit (e.g., the above described rail 65 or 66 or the movable platform 67) for moving the first pressure wave generation device, and the pressure wave generation device is configured to be capable of docking with each of the plurality of movable nozzles, and configured to switch the movable nozzle to be docked among the plurality of movable nozzles by moving using the moving unit.

[0087] With the ash removal system described in the above (5), it is possible to reduce the number of valves compared to the above configuration (3).

[0088] (6) In some embodiments, in the ash removal system according to any one of the above (1) to (5), the monitoring device includes: a combination of a scale (e.g., the scale 52 described above) and a camera (e.g., the above describe camera 51 described above); a laser displacement-measuring device (e.g., the laser displacement-measuring device 55 described above); an optical fiber thermometer (e.g., the optical fiber thermometer 56 described above); or a combination of two or more of the above three types of instruments.

[0089] According to the ash removal system described in the above (6), it is possible to monitor whether the parameter (accumulation thickness of ash or temperature of heat transfer tube) related to the accumulation thickness of ash is over the threshold value at each of the plurality of positions of the heat transfer tube group.

[0090] (7) In some embodiments, in the ash removal system described in the above (6), a plurality of fins (e.g., the above described fins 64) are provided so as to intersect with a heat transfer tube of the heat transfer tube group, and the monitoring device includes a camera configured to capture the scale disposed along the fins.

[0091] With the ash removal system described in the above (7), it is possible to determine the accumulation state of ash appropriately using the scale and the camera with regard to the heat transfer tube with fins where ash is likely to accumulate.

[0092] (8) In some embodiments, in the above ash removal system (6) or (7), a plurality of fins (e.g., the fins 64 described above) are provided so as intersect with a heat transfer tube

of the heat transfer tube group, and the monitoring device includes the laser displacement-measuring device configured to emit a laser along a longitudinal direction of the heat transfer tube at a position higher than upper ends of the plurality of fins.

[0093] With the ash removal system described in the above (8), it is possible to determine the accumulation state of ash appropriately using the laser displacement-measuring device with regard to the heat transfer tube with fins where ash is likely to accumulate.

[0094] (9) In some embodiments, in the ash removal system according to any one of the above (6) to (8), a plurality of fins (e.g., the fins 64 described above) are provided so as intersect with a heat transfer tube of the heat transfer tube group, each of the plurality of fins has a cut-out (e.g., the cut-out 64 described above) at a position on the same straight line (e.g., the straight line L1 described above), and the monitoring device includes the optical fiber thermometer disposed along the longitudinal direction of the heat transfer tube at the position of the cut-out of each of the plurality of fins.

[0095] With the ash removal system described in the above (9), it is possible to determine the accumulation state of ash appropriately using the optical fiber thermometer with regard to the heat transfer tube with fins where ash is likely to accumulate.

[0096] (10) In some embodiments, in the ash removal system according to any one of the above (1) to (9), the control device is configured to control the position and the orientation of the movable nozzle such that the tip of a movable nozzle of the at least one movable nozzle which discharges the pressure wave into a convection heat transfer chamber (e.g., the above described convection heat transfer chamber 14) of the boiler is oriented toward a wall of the convection heat transfer chamber in a flow-passage width direction.

[0097] Hypothetically, if the pressure wave is discharged with the tip of the movable nozzle oriented toward the middle in the flow passage width direction of the convection heat transfer chamber, ash separated from the heat transfer tube accumulates on the heat transfer tube below in the gravity direction, where the ash may start to develop and close the gap of the heat transfer tubes. In contrast, with the ash removal system described in the above (10), when the position and the direction of the tip of the movable nozzle are controlled so as to

discharge the pressure wave toward the wall in the flow passage width direction of the convection heat transfer chamber, separated ash falls through the gap between the heat transfer bank and the wall of the convection heat transfer chamber, and thus it is possible to suppress blockage of the gap of the heat transfer tube as described above.

5 [0098] (11) In some embodiments, in the ash removal system according to any one of the above (1) to (9), a plurality of fins (e.g., the above described fins 64) are provided so as intersect with a heat transfer tube of the heat transfer tube group, the plurality of fins are disposed along a flow direction of combustion gas of the boiler, and the control device is configured to control the tip of a movable nozzle of the at least one movable nozzle which
10 discharges the pressure wave to the fins to be oriented in a direction intersecting with each of the longitudinal direction of the heat transfer tube intersecting with fins and the flow direction of the combustion gas.

[0099] In a case where the heat transfer tube has fins, it is important to ensure the heat transfer area in addition to prevention of clogging. Thus, by discharging the pressure wave
15 while orienting the tip of the movable nozzle in the direction intersecting with each of the longitudinal direction of the heat transfer tube and the flow direction of exhaust gas as described in the above (11), it is possible to remove ash accumulating in the flow direction of exhaust gas (ash accumulating over fins arranged adjacently in the flow direction of exhaust gas, in particular) and maintain the heat transfer area.

20 [0100] (12) In some embodiments, in the ash removal system according to any one of the above (1) to (11), the monitoring device is configured to be capable of monitoring whether a parameter (the accumulation thickness of ash measured by the above described visible camera 51 or the laser displacement-measuring device 55 or the temperature of the heat transfer tube measured by the optical fiber thermometer 56) related to the accumulation state of ash at each
25 of the plurality of positions is not smaller than a threshold value, and the control device is configured to, if the parameter related to the accumulation state of ash is not smaller than the threshold value with regard to at least one position of the plurality of positions, move a tip of the movable nozzle toward the position where the parameter is not smaller than the threshold

value.

[0101] With the ash removal system described in the above (12), it is possible to discharge the pressure wave at the position where the parameter related to the accumulation state of ash is not smaller than the threshold value, and thus it is possible to efficiently remove ash at the position where the parameter related to the accumulation state of ash is not smaller than the threshold value, and suppress deterioration of the heat transfer efficiency of the boiler.

[0102] (13) In some embodiments, in the ash removal system described in the above (12), the control device is configured to, if the parameter related to the accumulation state of ash becomes smaller than the threshold value as a result of discharge of the pressure wave from the movable nozzle, stop operation of the pressure wave generation device supplying the pressure wave to the movable nozzle.

[0103] With the ash removal system described in the above (13), it is possible to suppress excessive discharge of the pressure wave and suppress an increase in the load of the heat transfer tube while suppressing an increase of the operation cost of the pressure wave generation device.

[0104] (14) In some embodiments, in the ash removal system according to any one of the above (1) to (13), the boiler includes a stoker-type incinerator (e.g., the above described incinerator 8).

[0105] In a case where the incinerator is of a stoker type, the fuel to be used contains a high amount of alkali metal and heavy metal, and thus the sintering rate of ash is higher and the melting point is lower than the case of a coal type, and thus ash is more likely to adhere and melt on the heat transfer tube of the heat transfer bank and the heat transfer tubes of the water wall tubes inside the boiler compared to a coal boiler.

[0106] (15) In some embodiments, in the ash removal system described in the above (3) or (4), the boiler includes: a stoker-type incinerator (e.g., the incinerator 8 described above); a radiation chamber (e.g., the first radiation chamber 10 or the second radiation chamber 12 described above) through which exhaust gas discharged from the incinerator passes; and a convection heat transfer chamber (e.g., the convection heat transfer chamber 14 described

above) disposed at a downstream side of the radiation chamber in a flow direction of the exhaust gas, including a heat transfer bank disposed therein, the plurality of movable nozzles include: a first movable nozzle (e.g., one of the movable nozzles 38A1, 38A2, 38B1 described above) disposed so as to be capable of discharging the pressure wave into the radiation chamber; and a second movable nozzle (e.g., one of the movable nozzles 38A3, 38B2 described above) disposed so as to be capable of discharging the pressure wave into the convection heat transfer chamber, and a distance between the first pressure wave generation device and the radiation chamber is smaller than a distance between the first pressure wave generation device and the convection heat transfer chamber.

[0107] The adhesion force of ash inside the boiler tends to increase toward the high-temperature side, that is, the upstream side, inside the boiler. Thus, by setting the distance between the first pressure wave generation device and the first radiation chamber to be smaller than the distance between the first pressure wave generation device and the convection heat transfer chamber as described in the above (15), it is possible to reduce attenuation of the pressure wave between the first pressure wave generation device and the first movable nozzle to be smaller than attenuation of the pressure wave between the first pressure wave generation device and the second movable nozzle. Accordingly, it is possible to enhance the pressure wave discharged from the first movable nozzle corresponding to the high-temperature side (upstream side) inside the boiler to be stronger than the pressure wave discharged from the second movable nozzle corresponding to the low-temperature side (downstream side) inside the boiler, and it is possible to remove ash having a high adhesion force at the high-temperature side inside the boiler efficiently.

CLAIMS

1. An ash removal system for removing ash which accumulates on a heat transfer tube group of a boiler, the ash removal system comprising:
 - 5 at least one pressure wave generation device for generating a pressure wave;
 - at least one movable nozzle configured to be capable of moving inside the boiler, for discharging the pressure wave generated by the at least one pressure wave generation device;
 - a monitoring device for monitoring an accumulation state of ash which accumulates on a heat transfer tube of the heat transfer tube group at each of a plurality of positions inside the
 - 10 boiler; and
 - a control device configured to control at least one of a position or an orientation of a tip of each of the at least one movable nozzle on the basis of the accumulation state monitored by the monitoring device.
- 15 2. The ash removal system according to claim 1,
 - wherein the at least one movable nozzle includes a plurality of movable nozzles for discharging the pressure wave generated by the at least one pressure wave generation device, and
 - wherein the control device is configured to control at least one of the position or the
 - 20 orientation of the tip of each of the plurality of movable nozzles on the basis of the accumulation state monitored by the monitoring device.
3. The ash removal system according to claim 2,
 - wherein the at least one pressure wave generation device includes a first pressure wave
 - 25 generation device for generating the pressure wave, and
 - wherein the ash removal system includes:
 - a first pipe part which is connecting to the first pressure wave generation device and through which the pressure wave generated by the first pressure wave generation device

passes;

a plurality of second pipe parts each connecting the first pipe part and corresponding one of the plurality of movable nozzles; and

a valve disposed in each of the plurality of second pipes.

5

4. The ash removal system according to claim 3,

wherein the plurality of movable nozzles include:

a first movable nozzle configured to be capable of discharging the pressure wave into a first space inside the boiler; and

10

a second movable nozzle configured to be capable of discharging the pressure wave into a second space inside the boiler disposed at a downstream side of the first space, and

wherein a distance between the first pressure wave generation device and an inlet of the pressure wave of the first movable nozzle is smaller than a distance between the first pressure wave generation device and an inlet of the pressure wave of the second movable nozzle.

15

5. The ash removal system according to claim 2,

wherein the at least one pressure wave generation device includes a first pressure wave generation device for generating the pressure wave,

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wherein the ash removal system includes a moving unit for moving the first pressure wave generation device, and

wherein the pressure wave generation device is configured to be capable of docking with each of the plurality of movable nozzles, and configured to switch the movable nozzle to be docked among the plurality of movable nozzles by moving using the moving unit.

25

6. The ash removal system according to any one of claims 1 to 5,

wherein the monitoring device includes: a combination of a scale and a camera; a laser displacement-measuring device; an optical fiber thermometer; or a combination of two or

more of the above three types of instruments.

7. The ash removal system according to claim 6,

wherein a plurality of fins are provided so as to intersect with a heat transfer tube of the

5 heat transfer tube group, and

wherein the monitoring device includes a camera configured to capture the scale disposed along the fins.

8. The ash removal system according to claim 6 or 7,

10 wherein a plurality of fins are provided so as intersect with a heat transfer tube of the heat transfer tube group, and

wherein the monitoring device includes the laser displacement-measuring device configured to emit a laser along a longitudinal direction of the heat transfer tube at a position higher than upper ends of the plurality of fins.

15

9. The ash removal system according to any one of claims 6 to 8,

wherein a plurality of fins are provided so as intersect with a heat transfer tube of the heat transfer tube group,

wherein each of the plurality of fins has a cut-out at a position on the same straight line,

20 and

wherein the monitoring device includes the optical fiber thermometer disposed along the longitudinal direction of the heat transfer tube at the position of the cut-out of each of the plurality of fins.

25 10. The ash removal system according to any one of claims 1 to 9,

wherein the control device is configured to control the position and the orientation of the movable nozzle such that the tip of a movable nozzle of the at least one movable nozzle which discharges the pressure wave into a convection heat transfer chamber of the boiler is oriented

toward a wall of the convection heat transfer chamber in a flow-passage width direction.

11. The ash removal system according to any one of claims 1 to 9,

wherein a plurality of fins are provided so as intersect with a heat transfer tube of the

5 heat transfer tube group,

wherein the plurality of fins are disposed along a flow direction of combustion gas of the boiler, and

wherein the control device is configured to control the tip of a movable nozzle of the at least one movable nozzle which discharges the pressure wave to the fins to be oriented in a
10 direction intersecting with the flow direction of the combustion gas.

12. The ash removal system according to any one of claims 1 to 11,

wherein the monitoring device is configured to be capable of monitoring whether a parameter related to the accumulation state of ash at each of the plurality of positions is not
15 smaller than a threshold value, and

wherein the control device is configured to, if the parameter related to the accumulation state of ash is not smaller than the threshold value with regard to at least one position of the plurality of positions, move a tip of the movable nozzle toward the position where the parameter is not smaller than the threshold value.

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13. The ash removal system according to claim 12,

wherein the control device is configured to, if the parameter related to the accumulation state of ash becomes smaller than the threshold value as a result of discharge of the pressure wave from the movable nozzle, stop operation of the pressure wave generation device
25 supplying the pressure wave to the movable nozzle.

14. The ash removal system according to any one of claims 1 to 13,

wherein the boiler includes a stoker-type incinerator.

15. The ash removal system according to claim 3 or 4,
wherein the boiler includes:

a stoker-type incinerator;

5 a radiation chamber through which exhaust gas discharged from the incinerator
passes; and

a convection heat transfer chamber disposed at a downstream side of the radiation
chamber in a flow direction of the exhaust gas, including a heat transfer bank disposed therein,
wherein the plurality of movable nozzles include:

10 a first movable nozzle disposed so as to be capable of discharging the pressure
wave into the radiation chamber; and

a second movable nozzle disposed so as to be capable of discharging the pressure
wave into the convection heat transfer chamber, and

wherein a distance between the first pressure wave generation device and the radiation
15 chamber is smaller than a distance between the first pressure wave generation device and the
convection heat transfer chamber.