

FLUIDIZED-BED HEAT RECOVERY APPARATUS

Technical field

[0001] The present invention relates to a fluidized-bed heat recovery apparatus having a function of a heat recovery chamber for uniformly oxidizing, such as combusting or gasifying, solid materials including municipal wastes, industrial wastes, coal, and incombustibles, and for stably recovering heat energy while smoothly discharging incombustibles.

Background Art

[0002] With economic development, about 44 million tons of general wastes, and about 400 million tons of industrial wastes are annually generated and treated. Some of these wastes are incinerated, and heat energy from the exhaust gas generated during the incineration process is effectively used for power generation and other purposes. In consideration of environmental issues, it is required to efficiently recover the heat energy.

However, in these wastes, particularly in the industrial wastes, the shape and properties of the wastes are very diverse and not constant. Further, a variety of incombustibles with irregular shapes are mixed. Therefore, it is difficult to achieve stable combustion and treatment, thus preventing the effective use of waste energy.

[0003] In order to effectively utilize energy from the general wastes and the industrial wastes, various systems have been developed for the purpose of recovering heat energy via oxidation reactions, such as incineration. Of such various systems, a fluidized-bed boiler is expected as a system capable of uniformly incinerating solid materials including incombustibles, and capable of stably recovering heat energy while smoothly discharging incombustibles. However, such a fluidized-bed boiler has the following drawback.

[0004] In a bubbling fluidized bed where fluidized medium is actively ascending and descending, the flow of the fluidized medium is only in the vertical direction. Therefore, dispersion of incinerated materials is insufficient, and thus uniform and stable combustion is difficult. Further, incombustibles having a higher specific gravity than the fluidized

medium are accumulated extensively on a furnace bed, and as a result, discharging of the incombustibles may be difficult, interfering with operations. Therefore, a method has been developed which forms a swirling flow of fluidized medium by varying a fluidizing velocity in a dense fluidized bed to improve mixing and dispersion of the incinerated materials, and can achieve uniform and stable combustion.

However, as in a conventional internally circulating fluidized-bed boiler (ICFB), a discharge port of the fluidized medium and the incombustibles is located near an outlet of a heat recovery chamber. Such an arrangement may form a fixed layer (non-fluidized region) in an upper portion of the discharge port, thereby preventing a smooth circulation of the fluidized medium from a heat recovery chamber to a main combustion chamber. Therefore, there has been a demand for solution of such issue.

Citation List

Patent Literature

[0005] Patent document 1: Japanese Laid-Open Patent Publication No. 07-056361

Summary of Invention

Technical Problem

[0006] The present invention has been made in view of the above drawback. It is therefore an object of the present invention to provide a fluidized-bed heat recovery apparatus capable of performing a smooth circulation of a fluidized medium from a heat recovery chamber (or a heat recovery region) to a main combustion chamber (or a main combustion region), uniformly combusting solid materials including incombustibles, and stably recovering heat energy while smoothly discharging the incombustibles.

Solution to Problem

[0007] In order to achieve the above object, according to one aspect of the present invention, there is provided a fluidized-bed heat recovery apparatus comprising: a fluidized-bed reactor having a fluidized bed disposed therein; a gas diffuser disposed at a furnace bed of the fluidized-bed reactor, the gas diffuser being configured to give different fluidizing velocities in the fluidized bed; and a heat recovery device having a

heat transfer surface, wherein a first weakly fluidized region, which is given a relatively small fluidizing velocity, is formed to generate a downward flow of the fluidized medium in the first weakly fluidized region, and a strongly fluidized region, which is given a relatively large fluidizing velocity, is formed to generate an upward flow of the fluidized medium in the strongly fluidized region, thereby forming a swirling flow of the fluidized medium in the fluidized bed, and a second weakly fluidized region, which is given a relatively small fluidizing velocity, is formed outside the strongly fluidized region to generate a downward flow of the fluidized medium in the second weakly fluidized region such that a part of the fluidized medium flows from the strongly fluidized region into the second weakly fluidized region, and the heat transfer surface of the heat recovery device is located in the second weakly fluidized region.

[0008] According to a preferred aspect of the present invention, the gas diffuser comprises: a first gas diffuser including a gas diffusion plate configured to give the relatively small fluidizing velocity in order to form the first weakly fluidized region; and a second gas diffuser including a plurality of gas diffuser tubes configured to give the relative large fluidizing velocity in order to form the strongly fluidized region, the plurality of gas diffuser tubes being arranged in a single stage or multiple stages along a vertical direction.

According to a preferred aspect of the present invention, the gas diffuser further comprises a third gas diffuser configured to give a relatively small fluidizing velocity in order to form the second weakly fluidized region, the third gas diffuser including a plurality of gas diffuser tubes or a gas diffusion plate, the plurality of gas diffuser tubes being arranged in a single stage or multiple stages along a vertical direction, the gas diffusion plate being inclined downwardly.

[0009] According to a preferred aspect of the present invention, solid materials as object to be treated are fed into the first weakly fluidized region, and incombustibles included in the solid materials are discharged by a fluidized-medium withdrawing conveyor provided below the gas diffuser.

According to a preferred aspect of the present invention, a partition wall is provided between the strongly fluidized region and the second weakly fluidized region.

[0010] According to a preferred aspect of the present invention, a passage for returning the fluidized medium from the second weakly fluidized region to the strongly fluidized region is provided between an upper stage and a lower stage of the multiple stages of the plurality of gas diffuser tubes constituting the second gas diffuser.

According to a preferred aspect of the present invention, a passage for returning the fluidized medium from the second weakly fluidized region to the strongly fluidized region is provided above the plurality of gas diffuser tubes arranged in the single stage constituting the second gas diffuser.

According to a preferred aspect of the present invention, the first gas diffuser includes a gas diffusion plate inclined downwardly toward the strongly fluidized region.

Advantages of the Invention

[0011] The present invention offers the following advantages:

(1) In the main combustion chamber (or the main combustion region) in which object to be treated (e.g., materials to be incinerated) is fed, a fluidized condition suitable for uniformly dispersing the object to be treated can be maintained, and the weakly fluidized region in the heat recovery chamber (or the heat recovery region) in which the heat recovery device is provided can be maintained under a fluidized condition suitable for heat recovery. Therefore, the apparatus according to the present invention can uniformly combust the object to be treated in the main combustion chamber (or the main combustion region), and can stably recover the heat energy in the heat recovery chamber (or the heat recovery region).

(2) The apparatus according to the present invention can optimize the fluidized condition of the fluidized medium returning from the weakly fluidized region in the heat recovery chamber (or the heat recovery region) to the strongly fluidized region in the main combustion chamber (or the main combustion region). Thus, the fluidized medium can smoothly circulate from the heat recovery chamber (or the heat recovery region) to

the main combustion chamber (or the main combustion region). Therefore, the fluidized medium can circulate well between the heat recovery chamber (or the heat recovery region) and the main combustion chamber, and controlling of such circulation can be achieved, while the incombustibles can be discharged smoothly, so that stable heat recovery can be achieved.

Brief Description of Drawings

[0012] FIG. 1 is a vertical cross-sectional view showing a first embodiment of a fluidized-bed heat recovery apparatus according to the present invention;

FIG. 2 is a vertical cross-sectional view showing a second embodiment of the fluidized-bed heat recovery apparatus according to the present invention;

FIG. 3 is a vertical cross-sectional view showing a third embodiment of the fluidized-bed heat recovery apparatus according to the present invention; and

FIG. 4 is a vertical cross-sectional view showing a fourth embodiment of the fluidized-bed heat recovery apparatus according to the present invention.

Description of Embodiments

[0013] Embodiments of a fluidized-bed heat recovery apparatus according to the present invention will be described below with reference to FIGS. 1 through 4. In FIGS. 1 through 4, identical or corresponding components are denoted by identical reference numerals, and will not be described in duplication.

FIG. 1 is a vertical cross-sectional view showing a first embodiment of a fluidized-bed heat recovery apparatus according to the present invention. As shown in FIG. 1, a fluidized-bed reactor 1 includes a furnace body 2 having a substantially square tubular shape. A fluidized bed in which a fluidized medium is fluidized is formed in the furnace body 2. The interior of the furnace body 2 is divided by a pair of right and left partition walls 3, 3 into a single main combustion chamber 4 located at a central portion of the furnace body 2, and two heat recovery chambers 5, 5 located at both sides of the furnace body 2. The main combustion chamber 4 has, at a bottom thereof, a gas

diffusion plate 7 for ejecting fluidizing air as a fluidizing gas into the furnace. This gas diffusion plate 7 has a chevron shape which is the highest at its center and is gradually lowered toward both side edges thereof. The gas diffusion plate 7 is a plate structure having a number of openings (or nozzles) through which the fluidizing air as the fluidizing gas is ejected into the furnace. The gas diffusion plate 7 constitutes a first gas diffuser.

[0014] At both sides of the gas diffusion plate 7, a plurality of gas diffuser tubes 8 and 9 for ejecting fluidizing air as a fluidizing gas into the furnace are disposed in two stages along a vertical direction. The gas diffuser tubes 8 and 9 are comprised of pipes having a number of openings (or nozzles) through which the fluidizing air as a fluidizing gas is ejected into the furnace. The gas diffuser tubes 8, 9 constitute a second gas diffuser. An arrangement of the gas diffuser tubes 8 and the gas diffuser tubes 9 arranged in two stages can be arbitrarily determined depending on an amount of incombustibles or other factors, such as overlapping arrangement or staggered arrangement along the vertical direction. The chevron-shaped gas diffusion plate 7 ejects the fluidizing air so as to give a relatively small fluidizing velocity. As a result, a weakly fluidized region WF (i.e., a rectangular region partitioned by dot line in FIG. 1), in which the fluidized medium is fluidized at a relatively small velocity, is formed above the gas diffusion plate 7. The weakly fluidized region WF in the main combustion chamber 4 constitutes a first weakly fluidized region. The gas diffuser tubes 8 and 9 arranged in two stages along the vertical direction eject the fluidizing air so as to give a relatively large fluidizing velocity. As a result, strongly fluidized regions SF (i.e., rectangular regions partitioned by dot lines in FIG. 1), in which the fluidized medium is fluidized actively, are formed above the gas diffuser tubes 8, 9.

[0015] On the other hand, in the heat recovery chambers 5 separated by the partition walls 3, heat recovery devices 10 which are constructed by heat transfer pipes or the like are disposed. Further, in a furnace bottom of each heat recovery chamber 5, a plurality of single-stage gas diffuser tubes 11 for ejecting fluidizing air as a fluidizing gas into the

furnace are disposed. The gas diffuser tubes 11 are comprised of pipes having a number of openings (or nozzles) through which the fluidizing air as the fluidizing gas is ejected into the furnace. The gas diffuser tubes 11 constitute a third gas diffuser. The single-stage gas diffuser tubes 11 eject the fluidizing air so as to give a relatively small fluidizing velocity. As a result, weakly fluidized regions WF (i.e., rectangular regions partitioned by dot lines in FIG. 1), in which the fluidized medium is fluidized at a relatively small velocity, are formed above the gas diffuser tubes 11. The weakly fluidized regions WF in the heat recovery chambers 5 constitute a second weakly fluidized region.

[0016] In the present embodiment, an amount of the fluidizing air supplied from the first gas diffuser into the first weakly fluidized region is such that u_0/u_{mf} is in a range of 0.5 to 3, preferably in a range of 1 to 2.5. An amount of the fluidizing air supplied from the second gas diffuser into the strongly fluidized region is such that u_0/u_{mf} is in a range of 4 to 20, preferably in a range of 6 to 12. An amount of the fluidizing air supplied from the third gas diffuser into the second weakly fluidized region is such that u_0/u_{mf} is in a range of 0 to 3, preferably in a range of 0.5 to 2. Here, " u_0 " represents a superficial velocity, and " u_{mf} " represents a minimum fluidizing superficial velocity.

[0017] The gas diffusion plate 7 in the weakly fluidized region WF of the main combustion chamber 4 is downwardly sloped (or inclined downwardly) towards the strongly fluidized regions SF above the gas diffuser tubes 8, 9 arranged in two stages along the vertical direction. Further, lower regions of the strongly fluidized regions SF below the gas diffuser tubes 8, 9 and lower regions of the heat recovery chambers 5 below the gas diffuser tubes 11 are in communication with a fluidized-medium withdrawing conveyor 13, so that the fluidized-medium withdrawing conveyor 13 discharges incombustibles, included in the fluidized medium and object to be incinerated, to the outside. A chute, in which the horizontal cross-sectional area of the furnace body 2 gradually decreases downward, is formed below the gas diffusion plate 7, the gas diffuser tubes 8, 9, and the gas diffuser tubes 11, so that the chute guides the incombustibles

together with the fluidized medium to the fluidized-medium withdrawing conveyor 13. An air pipe 15 is coupled to the gas diffusion plate 7, air pipes 16 are coupled to the upper-stage gas diffuser tubes 8 in the strongly fluidized regions SF, air pipes 17 are coupled to the lower-stage gas diffuser tubes 9, and air pipes 18 are coupled to the gas diffuser tubes 11 in the furnace bottoms of the heat recovery chambers 5.

[0018] In the fluidized-bed reactor 1 constructed as described above, an object W to be incinerated is fed from a feeding port (not shown) formed in the furnace body 2 into the weakly fluidized region WF of the main combustion chamber 4. The object W is combusted in a reducing atmosphere due to a low oxygen condition while being swallowed by a downward flow 21 of the fluidized medium. Thereafter, the fluidized medium flows toward the strongly fluidized region SF along the inclined surface of the gas diffusion plate 7. The object W that has flowed into the strongly fluidized region SF together with the fluidized medium ascends by an upward flow 22 of the fluidized medium while being sufficiently combusted in an oxidized atmosphere due to a large amount of oxygen.

Thereafter, the fluidized medium and the object W are returned to the weakly fluidized region WF again and swallowed by the downward flow 21, as indicated by arrows. Therefore, such a swirling flow of the fluidized medium disperses the object W in the fluidized bed, so that the object W can be uniformly and stably combusted.

On the other hand, a part of the upward flow 22 of the fluidized medium in the strongly fluidized region SF flows over the partition wall 3 into another weakly fluidized region WF in the heat recovery chamber 5. The fluidized medium gives heat to the heat recovery device 10 disposed in the heat recovery chamber 5 while descending in the weakly fluidized region WF, and is returned through an opening 6 formed in a lower portion of each partition wall 3 to the strongly fluidized region SF.

[0019] The weakly fluidized region WF, in which the heat recovery device 10 is provided, is in an oxidized atmosphere because of influx of the fluidized medium after sufficient combustion in the strongly fluidized region SF, and thus there is little risk of

reduction corrosion of the heat transfer surface of the heat recovery device 10. Further, the heat transfer surface of the heat recovery device 10 is hardly worn because of the weakly fluidized condition in the heat recovery chamber 5.

On the other hand, the incombustibles included in the object W are swallowed by
5 the downward flow 21 of the fluidized medium in the weakly fluidized region WF of the main combustion chamber 4. Thereafter, the fluidized medium changes its flow direction so as to move toward the strongly fluidized region SF. In this process, most of the incombustibles are separated and settled in the strongly fluidized region SF. However, since this strongly fluidized region SF has a gas diffuser tube structure, the
10 incombustibles pass through gaps between the gas diffuser tubes 8 and 9 without accumulating, and are then carried out together with the fluidized medium by the fluidized-medium withdrawing conveyor 13 installed at the bottom portion of the fluidized-bed reactor 1.

[0020] The upper- and lower-stage gas diffuser tubes 8 and 9 may be arranged along a
15 horizontal direction in a staggered manner or arranged in a grid manner. Provision of the gas diffuser tubes 8 and 9 disposed in two stages along the vertical direction enables this area to be sufficiently fluidized even if a horizontal pitch between the gas diffuser tubes 8 and 9 is increased. Moreover, increasing the pitch between the gas diffuser tubes 8 and 9 allows for discharging of larger incombustibles.

[0021] In FIG. 1, the fluidized medium and the incombustibles, which have overflowed
20 the partition wall 3 into the heat recovery chamber 5, move downward in the weakly fluidized region WF. The incombustibles are separated and settled near the furnace bottom. Since the heat recovery chamber 5 also has a gas diffuser tube structure, the incombustibles pass through gaps between the gas diffuser tubes 5 together with the
25 fluidized medium without accumulating, and are then carried out,, together with the fluidized medium and the incombustibles that have flowed from the strongly fluidized region SF, by the fluidized-medium withdrawing conveyor 13 installed at the lower portion of the fluidized-bed reactor 1.

[0022] The opening 6 located below the partition wall 3 is provided between the upper- and lower-stage gas diffuser tubes 8, 9 disposed below the strongly fluidized region SF, and the lower-stage gas diffuser tubes 9 are located below the opening 6, so that the fluidizing air or the fluidizing gas is adjusted. Specifically, the opening 6 serving as a passage for returning the fluidized medium from the weakly fluidized region WF in the heat recovery chamber 5 to the strongly fluidized region SF in the main combustion chamber 4 is formed between the upper- and lower-stage gas diffuser tubes 8, 9. With such structure, the lower-stage gas diffuser tubes 9 can optimize a fluidized condition of the fluidized medium returning from the weakly fluidized region WF in the heat recovery chamber 5 to the strongly fluidized region SF in the main combustion chamber 4. Further, the upper-stage gas diffuser tubes 8 can maintain an optimum fluidized condition of the fluidized medium in the strongly fluidized region SF in the main combustion chamber 4.

[0023] FIG. 2 is a vertical cross-sectional view showing a second embodiment of the fluidized-bed heat recovery apparatus according to the present invention. In the first embodiment shown in FIG. 1, the partition walls 3 are provided in order to prevent the object to be incinerated, which has been fed into the main combustion chamber 4, from entering the heat recovery chambers 5 without being combusted. Such unburned object may adversely affect the heat transfer tubes, because the unburned object is combusted in the heat recovery chambers 5, thus resulting in locally high temperatures. However, the partition walls 3 can be omitted depending on the properties of the object to be fed. Therefore, in the second embodiment shown in FIG. 2, the partition walls 3 are omitted. In this embodiment, the main combustion chamber 4 and the heat recovery chamber 5 in the first embodiment shown in FIG. 1 are referred to as main combustion region 4' and heat recovery region 5', respectively. In the second embodiment shown in FIG. 2, the number of components in the high-temperature fluidized bed can be reduced, and therefore a simplified structure can be provided. Further, a swirling flow of the fluidized medium is generated between the strongly fluidized region SF in the main combustion

region 4' and the weakly fluidized region WF in the heat recovery region 5', so that a high-temperature combustion gas and the fluidized medium flow between the strongly fluidized region SF and the weakly fluidized region WF more actively than in the case where the partition walls 3 in the first embodiment are installed. As a result, an efficiency of the heat recovery device 10 disposed in the weakly fluidized region WF can be improved.

[0024] FIG. 3 is a vertical cross-sectional view showing a third embodiment of the fluidized-bed heat recovery apparatus according to the present invention. In the first embodiment shown in FIG. 1, the gas diffuser tubes 11 are provided at the lower portion of the heat recovery chamber 5. As shown in FIG. 3, instead of the gas diffuser tubes 11, heat-recovery-chamber gas diffusion plates 25 can be provided. The heat-recovery-chamber gas diffusion plates 25 are downwardly sloped (or inclined downwardly) toward the openings 6, respectively, and thus the fluidized medium in the heat recovery chambers 5 is facilitated to move toward the openings 6. Therefore, a smoother circulation of the fluidized medium between the main combustion chamber 4 and the heat recovery chambers 5 can be performed.

[0025] FIG. 4 is a vertical cross-sectional view showing a fourth embodiment of the fluidized-bed heat recovery apparatus according to the present invention. In the first embodiment shown in FIG. 1, the gas diffuser tubes 8 and 9 arranged in two stages along the vertical direction are provided at both sides of the gas diffusion plate 7. As shown in FIG. 4, it is possible to provide only the single-stage gas diffuser tubes 9. The air pipes 17 are coupled to the gas diffuser tubes 9. In the present embodiment, the openings 6 serving as the passage for returning the fluidized medium from the weakly fluidized regions WF in the heat recovery chambers 5 to the strongly fluidized regions SF in the main combustion chamber 4 are formed above the gas diffuser tubes 9. The gas diffuser tubes 9 can optimize the fluidized condition of the fluidized medium returning from the weakly fluidized regions WF in the heat recovery chambers 5 to the strongly fluidized regions SF in the main combustion chamber 4.

[0026] While the embodiments of the present invention have been described above, the present invention is not limited to the above embodiments, but may be reduced to practice in various different forms within the scope of the technical idea thereof.

Industrial Applicability

- 5 [0027] The present invention is applicable to a fluidized-bed heat recovery apparatus having a function of a heat recovery chamber for uniformly oxidizing, such as combusting or gasifying, solid materials including municipal wastes, industrial wastes, coal, and incombustibles, and for stably recovering heat energy while smoothly discharging incombustibles.

10 **Reference Signs List**

- [0028] 1 fluidized-bed reactor
2 furnace body
3 partition wall
4 main combustion chamber
15 4' main combustion region
5 heat recovery chamber
5' heat recovery region
6 opening
7 gas diffusion plate
20 8, 9, 11 gas diffuser tube
10 heat recovery device
13 fluidized-medium withdrawing conveyor
15, 16, 17, 18 air pipe
21 downward flow
25 22 upward flow
25 heat-recovery-chamber gas diffusion plate
W object to be incinerated
SF strongly fluidized region

WF weakly fluidized region

CLAIMS

[Claim 1] A fluidized-bed heat recovery apparatus comprising:

a fluidized-bed reactor having a fluidized bed disposed therein;

5 a gas diffuser disposed at a furnace bed of the fluidized-bed reactor, the gas diffuser being configured to give different fluidizing velocities in the fluidized bed; and
a heat recovery device having a heat transfer surface,

wherein a first weakly fluidized region, which is given a relatively small fluidizing velocity, is formed to generate a downward flow of the fluidized medium in the first weakly fluidized region, and a strongly fluidized region, which is given a relatively
10 large fluidizing velocity, is formed to generate an upward flow of the fluidized medium in the strongly fluidized region, thereby forming a swirling flow of the fluidized medium in the fluidized bed, and

a second weakly fluidized region, which is given a relatively small fluidizing velocity, is formed outside the strongly fluidized region to generate a downward flow of
15 the fluidized medium in the second weakly fluidized region such that a part of the fluidized medium flows from the strongly fluidized region into the second weakly fluidized region, and

the heat transfer surface of the heat recovery device is located in the second weakly fluidized region.
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[Claim 2] The fluidized-bed heat recovery apparatus according to claim 1, wherein the gas diffuser comprises:

a first gas diffuser including a gas diffusion plate configured to give the relatively small fluidizing velocity in order to form the first weakly fluidized region; and

25 a second gas diffuser including a plurality of gas diffuser tubes configured to give the relative large fluidizing velocity in order to form the strongly fluidized region, the plurality of gas diffuser tubes being arranged in a single stage or multiple stages along a vertical direction.

[Claim 3] The fluidized-bed heat recovery apparatus according to claim 2, wherein the gas diffuser further comprises a third gas diffuser configured to give a relatively small fluidizing velocity in order to form the second weakly fluidized region, the third gas
5 diffuser including a plurality of gas diffuser tubes or a gas diffusion plate, the plurality of gas diffuser tubes being arranged in a single stage or multiple stages along a vertical direction, the gas diffusion plate being inclined downwardly.

[Claim 4] The fluidized-bed heat recovery apparatus according to any one of claims 1
10 through 3, wherein solid materials as object to be treated are fed into the first weakly fluidized region, and incombustibles included in the solid materials are discharged by a fluidized-medium withdrawing conveyor provided below the gas diffuser.

[Claim 5] The fluidized-bed heat recovery apparatus according to any one of claims 1
15 through 4, wherein a partition wall is provided between the strongly fluidized region and the second weakly fluidized region.

[Claim 6] The fluidized-bed heat recovery apparatus according to claim 2, wherein a passage for returning the fluidized medium from the second weakly fluidized region to
20 the strongly fluidized region is provided between an upper stage and a lower stage of the multiple stages of the plurality of gas diffuser tubes constituting the second gas diffuser.

[Claim 7] The fluidized-bed heat recovery apparatus according to claim 2, wherein a passage for returning the fluidized medium from the second weakly fluidized region to
25 the strongly fluidized region is provided above the plurality of gas diffuser tubes arranged in the single stage constituting the second gas diffuser.

[Claim 8] The fluidized-bed heat recovery apparatus according to claim 2, wherein the

first gas diffuser includes a gas diffusion plate inclined downwardly toward the strongly fluidized region.