(54) Title: WATERWALLS IN A FLUIDIZED BED REACTOR

(75) Abstract

A fluidized bed reactor generating heat has in its bottom part a grid (5) for introduction of fluidising gas into the reactor and walls (2) being made as waterwalls in which vertical water tubes are combined by flat plate material (15). The waterwalls are refractory lined (8) in their lower part to withstand erosion and heat. The water tubes are bent outwards at an angle to the vertical plane in the intermediate section between the uncovered upper waterwall section and the refractory lined upper waterwall section in order to minimize erosion due to particles flowing downwards along the walls in the reactor.
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WATERWALLS IN A FLUIDIZED BED REACTOR

This invention relates to a novel geometry of the peripheral waterwalls in a vertical fluidized bed reactor and more particularly to the geometry of the waterwalls in an intermediate region between the upper uncovered waterwall region and the lower refractory lined waterwall region.

The fluidized bed reactors are used in a variety of different combustion, heat transfer, chemical or metallurgical processes. Depending on the process, different bed materials are fluidized or circulated in the system. In combustion processes particulate fuels such as coal, coke, lignite, wood, wood waste, coal waste or peat as well as other particulate matter such as sand, ash, sulfur absorbent, catalysts or metalloxides can be the constituents of the fluidized bed.

A fluidized bed reactor generating heat comprises an upright reactor chamber, having substantially vertical peripheral walls. The walls are made as waterwalls or tube walls in which vertical tubes are combined by flat plate material or "fins". The walls in the lower part of the reactor are usually refractory lined to withstand the heat and erosion. The violent agitation of abrading particles and the relatively high concentration of solid material lead to most erosive conditions in the bottom region of the reactor.

At specific locations in the reactor there are both downward and upward flows of bed material. The absolute mass flow varies in radial and axial direction of the reactor chamber. The downward mass flow is extreme near the peripheral walls. As the density of particles increases downwards in the reactor chamber, even the downward falling film of particles along the peripheral walls increases. The downward falling film can be as thick as 10 - 50 mm, or thicker. Any change in the direction of the downward falling film causes erosion.
The upper edge of the refractory lining in the waterwall construction forms a shoulder in the reactor chamber and causes eddy flow of the downward falling film of bed material. The direction of the film falling vertically downward along the "fins" combining two adjacent tubes, is partly changed and is directed to flow along the border line of the refractory lining. The eddy flow and horizontal flow of particles along the border line causes heavy erosion of the waterwall tubes especially close to the refractory lining. The erosion is especially problematic in solid fuel fired boilers having highly erosive conditions.

The tubes in the waterwalls have to be inspected from time to time and eventually recoated with sacrificial material or replaced by new tubes. Extensive downtime is required to cut out the deteriorated tubes and to install new ones or renew the sacrificial surface. Both are laborious and time consuming process.

While the problem with erosion of tubes in fluidized bed reactors is well known and different solutions have been suggested to minimize the erosion, such solutions have not been entirely successful. A refractory lining shielding the tubes high up in the reactor would decrease the erosion but it would also decrease the heat transfer to the tubes.

Welding a layer, a sacrificial surface, on the tubes in particularly vulnerable regions has been tried. The welds would, however, not last for a very long time in highly erosive surroundings. It has also been suggested to cover the tubes with wear resisting material, i.e. sintered metal or ceramic materials. This is an expensive solution and decreases the heat transfer in the tubes.

It has also been suggested to decrease the velocity of the flow along the tubewalls by welding studs or other obstacles decreasing the flow velocity of particles on the tubes.
The high velocity in the reactor is, however, advantageous for the heat transfer at the tube walls and should not necessarily be decreased. It has also been suggested in the Swedish Patent SE 454,725 to weld curved segments on the tubes at especially hard wearing locations.

It has further been suggested in the Swedish Patent SE 452,360 to arrange the entire reactor walls upwardly inwardly inclined to decrease erosion along the walls. This is a very peculiar construction and not very easily accomplished.

It is therefore an object of the present invention to provide an arrangement of the tube walls in a fluidized bed reactor which minimizes the erosion at the locations close to the refractory lined part of the walls.

It is still another object of the present invention to reduce the downtime in fluidized bed boilers which is due to tube replacements.

In order to achieve the above objects, the tube wall in the intermediate zone between the non-refractory lined tube wall and the refractory lined tube wall is bent downwards and outwards at an angle to the vertical plane.

The tube wall is either bent back to vertical at a distance downwards from the first bend or the tube wall may be bent inwards on an angle to form an inner sloped wall of the combustion chamber. Especially the front and rear walls could be formed as sloped walls, the side walls could be vertical.

The above brief description as well as further objects, features and advantages of the present invention will be more fully appreciated by reference to the following detailed description of presently preferred embodiments taken in conjunction with the accompanying drawings wherein:
Fig. 1 is a cross sectional view of the lower part of a fluidized bed reactor.

Fig. 2 is an enlarged schematic view of a part of the intermediate region between the upper uncovered tube wall and the lower refractory lined tube wall.

Fig. 3 is a cross sectional view of Fig. 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 shows the lower part of a fluidized bed reactor having a combustion chamber 1 and peripheral tube walls 2, such as membranewalls. The particulate material in the combustion chamber is fluidized by air being introduced from an air chamber 3 beneath the combustion chamber. The air is distributed into the combustion chamber from the air chamber through nozzles 4 in a grid plate 5. If other gas than air is used to fluidize the particulate material in the combustion chamber, air or oxidizing gas has to be introduced through other inlets not shown. Fuel, additives and other particulate material or secondary gas, if needed, are supplied through inlets not shown in the figure.

The waterwalls are uncovered in the upper part of the combustion chamber 6. In the lower part of the combustion chamber 7 the waterwalls are lined with refractory material 8. In an intermediate zone 9 between the upper uncovered waterwall 10 and the lower refractory lined waterwall 11 the waterwalls are bent outwards. The height of the refractory lined wall part to the height of the total vertical wall in a combustion chamber is usually 1:3 to 1:10.

The intermediate zone can be seen more in detail in figures 2 and 3. The waterwall 10 is at a point 12 bent downwards and outwards at an angle $\alpha$ when coming to the intermediate zone between the uncovered and the refractory lined water-
wall. The angle $\alpha$ between the bent waterwall and the vertical plane can be $5 - 30^\circ$. In most cases an angle of about $10 - 20^\circ$ is sufficient.

The refractory lining 8 of the waterwall begins at the bend. The inner surface 13 of the lining forms a straight downward extension of the inner surface 14 of the flat plates or fins 15 combining two adjacent tubes 10. The inner surface of the refractory lining will be in the same vertical plane as the vertical plane of the flat plates or fins. The construction avoids the shoulder usually formed by refractory lining in a straight vertical waterwall and lets the falling film pass the tubes without eddy of the particle flow. A downward particle flow along the fins 15 can then continue downwards along the refractory lining and is not caused to change its direction. Also particles flowing downwards along the tubes 10 can continue their flow without disturbances. The bending of the waterwall protects the wall tubes very effectively.

The uppermost relatively thin layer of refractory lining may be protected by a cover or a shielding plate 17 welded as a vertical extension to the plate 15, as shown in figure 4, in order to protect the refractory lining at its uppermost part.

If needed, a stay can be welded on the outside surface of the waterwall to stake the waterwall at the bend.

The waterwall in the intermediate zone 9 is bent back to vertical at a lower point 16. The waterwall may even be bent further inwards if the cross sectional area of the lower part of the combustion chamber has to be decreased downwards as can be seen in figure 1 and 5. If the waterwall is bent further inwards the inner surface of the refractory lining forms a downward and inward sloping surface of the refractory beginning at a vertical plane outwards from the vertical plane of the fins.
The waterwalls may secondly be bent inwards at an angle of about 5 - 30° from vertical. The distance between the first and the second bend may be about 200 - 400 mm.

The intermediate part 9 of the waterwalls can easily be made as a module system with different bends and can be easily connected to the straight wall parts.

The refractory lining may according to another embodiment of the invention be made with an edge or a shoulder part as shown in figure 5 where the lining begins beneath the first bed in the waterwall. The shoulder may form an acute angle $\beta$ with the vertical plane. The angle $\beta$ is preferably chosen so that particles will not pile on the shoulder, e.g. an angle of about 45° may be used. In this embodiment the upper surface of the refractory lining may be shielded by a steel plate or like to protect the refractory lining from being deteriorated.

The refractory lining may according to a further embodiment of the invention be made with a sloped shoulder part as shown in figure 6 where the lining also begins beneath the first bend in the waterwall. The particle film falling down along the waterwall will slide downward after impact with refractory lining.

In the embodiments shown in figures 5 and 6 the downwards flowing particles will still continue their flow without heavy turbulence causing erosion at the border line of the refractory. The thickness of the refractory can in these embodiments be chosen independently of bends in the walls. The refractory layer begins preferably under the level at which the inner surface of the tubes after the bend has reached the vertical plane of the plates 15. At this level the particles flowing down from the plates 15 do not cause eroding turbulence at the border line between the tubes and the refractory lining.
The tube surface at the bend can be additionally protected by sacrificial material, which in this case does not wear out very easily as the turbulent particle flow near the tube surface is decreased.

Bifurcated water tubes 18 as shown in figure 6 may be installed at the intermediate section in the corners of the reactor chamber for sealing the waterwall at the bend in the corners. At the corners the distances between the tubes will increase when the tubes are bent. Additional tubes, e.g. bifurcated tubes, may be used to seal the spacings between the tubes.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that other embodiments, forms and modifications of the invention coming within proper scope and spirit of the appended claims will, of course, readily suggest themselves to those skilled in the art. It is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted in an illustrative and not in a limiting sense.
What we claim:

1. A reactor chamber in a fluidized bed reactor having a grid at the bottom of the reactor chamber and walls defining the reactor chamber horizontally, said walls having
   - a substantially vertical upper waterwall section in the upper part, the tubes in a waterwall being combined with fins or flat plates to form the waterwall;
   - a refractory lined lower wall section in the lower part, and
   - an intermediate waterwall section between the upper waterwall section and the refractory lined lower wall section, characterized in that
     - a waterwall in the intermediate waterwall section is bent outwards at an angle to the vertical plane.

2. A reactor chamber according to claim 1, characterized in that
   - a waterwall in the intermediate waterwall section is first bent outwards and secondly bent back to vertical.

3. A reactor chamber according to claim 1, characterized in that
   - a waterwall in the intermediate waterwall section is first bent outwards and secondly bent inwards to form an angle with the vertical plane.

4. A reactor chamber according to claim 3, characterized in that
   - in a front and/or in a rear wall in a reactor chamber a waterwall in the intermediate waterwall section is first bent outwards and secondly bent inwards to form an angle with the vertical plane.

5. A reactor chamber according to claim 1, characterized in that
   - at the intermediate waterwall section the inner surface of the refractory lining is in the same plane as the
vertical plane of the fins or flat plates in the upper waterwall section above the refractory lining.

6. A reactor chamber according to claim 5, characterized in that
   - a shielding plate is disposed, as a vertical extension of the vertical fins or flat plates, to protect the refractory lining at its uppermost part.

7. A reactor chamber according to claim 1, characterized in that
   - at the intermediate waterwall section the inner surface of the refractory lining forms a downwards and inwards sloping surface beginning at a vertical plane outwards from the vertical plane of the fins or flat plates.

8. A reactor chamber according to claim 1, characterized in that
   - at the intermediate waterwall section the refractory lining begins at a distance downwards from the first bend of the waterwall and forms an edge with the waterwall.

9. A reactor chamber according to claim 1, characterized in that
   - the height of the refractory lined section is 1:3 to 1:10 of the height of the waterwall section.

10. A reactor chamber according to claims 2, 3 or 4, characterized in that
    - the distance between the first bend and the second bend is 200 - 400 mm.

11. A reactor chamber according to claim 1, characterized in that
    - the waterwall is first bent outwards at an angle of 5-30° from vertical.
12. A reactor chamber according to claims 3 or 4, characterized in that
- the waterwall is secondly bent inwards at an angle of 5-30° from vertical.

13. A reactor chamber according to claim 1, characterized in that
- at the intermediate waterwall section, at the corners of the reactor chamber, bifurcated watertubes are installed for sealing the waterwall at the bend of the waterwall.

14. A wall in a reactor chamber in a fluidized bed reactor, said wall including a waterwall, which is refractory lined in its lower part, characterized in that
- said waterwall is bent outwards at a location immediately above the refractory lined waterwall part.
INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: F 23 M 5/08, F 22 B 37/10

II. FIELDS SEARCHED

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Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched

SE, DK, FI, NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>SE, B, 452360 (GÖTAVERKEN ENERGY SYSTEMS AB) 23 November 1987, see the whole document</td>
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  * Y* document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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IV. CERTIFICATION

Date of the Actual Completion of the International Search: 11th May 1990

Date of Mailing of this International Search Report: 1990-05-17

International Searching Authority: SWEDISH PATENT OFFICE

Signature of Authorized Officer: Anette Hall

Form PCT/ISA/210 (second sheet) (January 1985)
ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/FI 90/00034

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the Swedish Patent Office EDP file on 90-05-07. The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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