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(54) Process and Apparatus for the Preparation of synthesis gas

(57) Process and apparatus for producing synthesis gas by partial combustion of carbon-containing fuel with oxygen-containing gas in a reactor in which molten slag is removed through a slag discharge in the bottom and passed by gravity into a water bath where it is solidified by quenching. The slag is passed in the water bath through a sloping screen covering the total horizontal cross section of the bath and slag captured by the screen is conducted to the wall of the bath.

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PROCESS AND APPARATUS FOR THE PREPARATION OF SYNTHESIS GAS

The invention relates to a process for the preparation of synthesis gas by the partial combustion of a carbon-containing fuel with an oxygen-containing gas in a reactor in which the synthesis gas is discharged through a gas outlet at the top of the reactor and slag is removed through a slag discharge in the bottom of the reactor and passed by gravity into a water bath where it is solidified by quenching.

The partial combustion of carbon-containing fuel with substantially pure oxygen as oxygen-containing gas yields synthesis gas mainly consisting of carbon monoxide and hydrogen. When the oxygen-containing gas is air or oxygen-enriched air, the synthesis gas formed of course also contains a substantial quantity of nitrogen. By carbon-containing fuel is generally meant coal or another solid fuel, such as brown coal, peat, wood, coke, soot etc., but liquid fuels, such as tar sand oil or shale oil, and mixtures of liquid and particulate solid fuels, are also possible.

Preferably, a moderator is also introduced into the reactor. The object of the moderator is to exercise a moderating effect on the temperature on the reactor. This is ensured by endothermic reaction between the moderator and the reactants and/or products of the synthesis gas preparation. Suitable moderators are steam and carbon dioxide.

The gasification is preferably carried out at a temperature in the range from 1200 to 1700°C and at a pressure in the range from 1 to 200 bar.

The reactor in which the preparation of synthesis gas takes place may have the shape of a sphere, cone block or a cylinder.

Preferably the reactor mainly has the shape of a circular cylinder.

The supply of carbon-containing fuel and oxygen-containing gas can take place through the bottom of the reactor. It is also possible to supply one of the reactants through the bottom of the reactor and one or more others through the side wall of the reactor. However, both the fuel and the oxygen-containing gas and the moderator are preferably supplied through the side wall of the reactor. This is advantageously performed by means of at least two burners arranged symmetrically in relation to the reactor axis in a low part of the side wall.

Part of the slag is entrained by the synthesis gas as small droplets and leaves the reactor via the gas outlet at the top of the reactor.

The remainder of the liquid slag formed in the combustion reaction drops down and is drained through the slag discharge located in the reactor bottom.

To remove the slag from the gasifying process, it is already known to arrange a quenching water bath at the bottom of the gasifying vessel, in which water bath the slag descending due to its gravity, is captured, quenched, and forms clinker granules or agglomerations. After such granulation, the clinker is periodically or continuously removed from the water bath by means of conventional arrangements.

As a result of the cooling or quenching of the slag in the water bath and the attendant violent conditions, most of the clinker granulate is relatively small in size. However, as shown by experience, at the start-up, shut-down and disturbances or upsets of the process large granules or clinker agglomerations form in the water bath, and it is very difficult to remove such relatively large granules or agglomerations from the water bath.

According to the present invention this problem is solved by arranging a screen in the water bath which screen holds back the relatively large clinker agglomerations while the relatively small granules pass through it.

The present invention therefore relates to a process for producing synthesis gas by the partial combustion of a carbon-containing fuel with an oxygen-containing gas in a reactor in which the synthesis gas is discharged through a gas outlet at the top of the reactor and molten slag is removed through a slag discharge in the bottom of the reactor and passed by gravity into a water bath where it is solidified by quenching, characterized in that at least part of the slag is passed in the water bath through a sloping screen covering the total horizontal cross section of the bath and slag captured by the screen is conducted to the wall of the bath.

The invention also relates to an apparatus for the partial combustion of a carbon-containing fuel with an oxygen-containing gas which apparatus comprises a reactor which is equipped with a gas outlet at the top and a slag discharge in the bottom, debouching into a water bath characterized in that the water bath is provided with a sloping screen covering its total horizontal cross section.

When a slag droplets-carrying stream of synthesis gas is passed upwards through the reactor, slag droplets collide with each other and fall down to the bottom of the reactor. The gas is thus at least partly freed from slag droplets. The collected liquid slag drips from the reactor bottom and drops down as small droplets through the slag discharge into the water bath. Applicants have now found that during the start-up, shut-down, disturbances or upsets of the gasification process the slag droplets coagulate and solidify to relatively large clinker agglomerations while during the normal course of the process relatively small solid slag granules are formed in the water bath.

The screen is obliquely placed in the water bath. Consequently, the large clinker agglomerates present on the screen slide to the lowest part of the screen, while the small slag granules pass through the openings in the screen to the bottom of the water bath from which they can easily be discharged.

In order to ensure this the screen is preferably flat and arranged obliquely in the reactor. The retained clinker agglomerates now slide on the screen to the lowest points where the screen is fitted to the water bath wall. After the gasification process has been shut down the clinker agglomerates are advantageously removed from the screen through one or more openings in the water bath wall which are locked, suitably by one or more removable flanges, during the normal operation of the gasification process.

All captured clinker agglomerates are passed downwards to the wall. This is for a substantial part determined by the slope at which the screen is fitted in the water bath. It has appeared very suitable that the screen is fitted at an angle of 20-70° to the reactor axis. The screen is most preferably placed at an angle of about 45°. It is thus ensured that practically all captured solid slag agglomerates are passed to at least that part of the reactor wall in which the opening(s) for removing agglomerates mentioned hereinbefore is (are) situated.

In another preferred embodiment of the invention the screen has the shape of a part of a cylinder wall. The convex side of the cylinder wall is directed upwards. The screen then has the shape of a saddle. The slag agglomerates retained by the screen slide to the reactor wall along the saddle surface to both its deepest points. Since these points are situated at the side of the saddle, the slag agglomerates slide over the side of the saddle to the two lowest points of intersection between the cylinder wall of screen and that of the water bath. As a result the solid slag agglomerates are unequally divided over the reactor wall also in said embodiment.

If the cylinder wall is fitted in the reactor with the convex side directed downwards, a "gutter" is formed. If the cylinder wall is fitted horizontally, the captured slag then slides to the centre of the gutter and blocks the centre. So this is rather unattractive. Therefore the gutter is advantageously fitted in the reactor obliquely, so that the lowest point of the gutter lies against the reactor wall. The captured slag slides to said lowest point. The cylinder radius/reactor radius ratio is preferably 1:1 to 10:1.

If use is made of the above-described preferred embodiments, the captured solidified slag slides to part(s) of the reactor wall, from which it is periodically removed through openings therein, which openings are closed during normal operation of the gasification process.

In some cases it is advantageous to pass the captured solidified slag downwards as evenly as possible distributed over the circumference of the reactor wall. It is thus ensured that no part of the periphery of the reactor wall is extra heavily loaded with the slag agglomerates. This object is preferably reached by using a screen having the form of a dome-shaped cap. Owing to the domed shape the captured slag agglomerates slide evenly to the lowest points on the screen. In order to ensure that the captured slag agglomerates on the dome-shaped cap start sliding to the lowest points the curve of the dome must be sufficient. Therefore, the radius ratio of the sphere to the reactor is preferably 1:1 to 10:1.

If a slag agglomerate falls on the centre of the dome-shaped screen, the curve of the screen is rather small at said place. Consequently, there is a risk of the agglomerate not sliding to the wall, but staying at its place. This risk is rather small if the screen has the shape of a conical surface the apex of which is directed upwards. By choosing the suitable height of the cone in relation to the radius of its base, it is ensured that the conical surface is sufficiently oblique. A suitable angle of the cone-describing lines to the base is in the range from 20-70° so that the apex angle of the conical surface is preferably in the range from 40 to 140°.

Preferably the apex of the conical surface is situated on the centre line of the water bath and its base is adjacent to the wall of the water bath. In this way the clinker agglomerates are evenly distributed over the space between the lower part of the conical surface and the inside of the water bath wall. From this space the agglomerates can be removed periodically through openings in the water bath wall which are closed during normal operation.

The screens suitably consist of a lattice work of bars. For example, the lattice work may consist of a bundle of parallel bars attached to the reactor wall. It is also possible to make connections between the parallel bars so that the shape of a perforated plate is formed.

Although it is possible that part of screen stands out above the water level of the water bath, according to a preferred embodiment of the present invention the total screen is immersed in the water bath. In this way the screen comes only in contact with solidified slag which does not stick to the screen whereas the molten slag which drops down from the reactor outlet is sticky and would adhere to the screen if not immersed in water.

In order to improve the sliding of the clinker agglomerates along the upside of the screen the screen is preferably provided with vibrating means so that the screen is advantageously vibrated continuously or intermittently in order to obviate blocking of the screen. The small solidified slag granules thus easily pass through the openings in the screen. The large clinker agglomerations slide over the screen surface to the space neighbouring the water bath wall. As the large clinker agglomerations are predominantly produced during the start-up, shut-down, disturbance or upset periods of the gasification process only part of the screen surface will be covered by the agglomerations during normal process run. After the start-up period predominantly small solid slag granules are formed which pass through the openings of that part of the screen which is not covered by the large agglomerations, to the bottom of water bath from which they are removed by means of a proper conventional sluicing system.

The invention is now further illustrated with reference to the Figure. Control and regulating devices, cooling systems, insulation, etc., are not shown in the Figure which gives a diagrammatic representation of part of an apparatus for the partial combustion of a carbon-containing fuel.

Via burners 2 in the side wall of a reactor 1 (only partly shown) a carbon-containing fuel, an oxygen-containing gas and possibly a moderator are introduced into the reactor 1. The partial combustion yields synthesis gas and slag. The greater part of the liquid slag formed leaves the reactor via a slag discharge 3 in the bottom of the reactor 1. The synthesis gas flows upwards and leaves the reactor 1 via a gas outlet (not shown) at the top of the reactor. The liquid slag drips down from the outlet 3 and falls into a water bath 4 where it solidifies. Small solid slag granules which are predominantly formed after the start-up period of the gasification process and which have a diameter in the range from 0.1 to 40 mm pass downwards through the openings in the screen 5 into a slag discharge 6. Through valves 7 and 8 they are passed into a slag container 9 from which they are sluiced out via valves 10 and 11.

Large clinker agglomerates which are predominantly formed during the start-up period of the gasification process and which have a diameter in the range from 40 to 1000 mm cannot pass the openings of the screen 5. They slide down over the conical surface of the screen 5 to the bottom of the annular space between the screen 5 and the wall of the water bath 4. From this space they are removed at the end of the gasification run period after the gasification unit has been shut down. This removal takes place via openings 12 in the water bath wall which are closed, e.g. by removable flanges (not shown) during the normal operation of the gasification process.

<u>EXAMPLE</u>

The following experiment was carried out in an apparatus as shown in the Fig., in which the screen consisted of a perforated cone having circular perforations with a diameter of 40 mm while 95% of the conical surface consists of the total perforations.

An hourly quantity of 6.6 tons of coal powder in nitrogen, 5.6 tons of oxygen-containing gas and 0.6 tons of steam was introduced into the 4 m³ reactor via the burners.

The coal powder had an average particle size of 5.10^{-5} m and had the following composition on a dry and ashless basis:

C	81.5	% wt.
H	5.3	" "
N	1.6	" "
O	10.8	" "
S	0.8	" "

The ash content was 8% by weight and the moisture content 1% by weight. The oxygen-containing gas consisted of 99% pure oxygen.

The pressure in the reactor was 30 bar.

An hourly quantity of 12 tons of synthesis gas of 1400°C having the following composition was removed via the gas discharge (calculated as dry gas):

CO	66.1	% vol.
H_2	31.5	" "
CO_2	2.0	" "
H_2S	0.3	" "
CH_4	0.1	" "

A quantity of 178 kg/h of slag was entrained by the synthesis gas.

The quantity of slag drawn off via the slag discharge was 350 kg per hour. It dripped down into the water bath where it solidified. During the start-up period of 1 hour 10 kg clinker agglomerates were formed having a diameter in the range from 40 to 100 mm. They did not pass through the screen but were kept in the water bath at the bottom of the annular space between the screen and the water bath wall. They were removed through openings in the water bath at the end of the gasification run which lasted 240 hours.

During the normal gasification run after the start-up period solid slag granules having a diameter in the range from 0.1 to 20 mm were formed in the water bath. They passed through the openings in the screen to the bottom of the water bath from which they were removed periodically.

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CLAIMS

1. A process for producing synthesis gas by the partial combustion of a carbon-containing fuel with an oxygen-containing gas in a reactor in which the synthesis gas is discharged through a gas outlet at the top of the reactor and molten slag is removed through a slag discharge in the bottom of the reactor and passed by gravity into a water bath where it is solidified by quenching, characterized in that at least part of the slag is passed in the water bath through a sloping screen covering the total horizontal cross section of the bath and slag captured by the screen is conducted to the wall of the bath.

2. A process as claimed in claim 1, characterized in that the screen is flat and placed obliquely in the reactor.

3. A process as claimed in claim 2, characterized in that the screen is placed at an angle of 20-70° to the reactor axis.

4. A process as claimed in claim 1, characterized in that the screen has the shape of a part of a cylinder wall.

5. A process as claimed in claim 1, characterized in that the screen has the shape of a part of a spherical surface.

6. A process as claimed in claim 5, characterized in that the radius ratio of the sphere and the reactor ranges from 1:1 to 10:1.

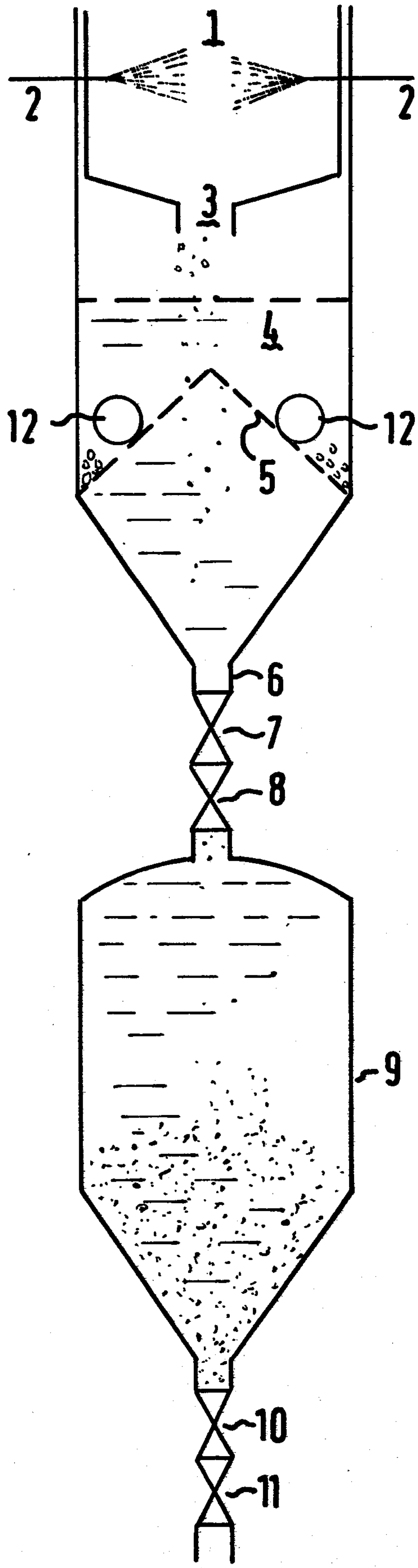
7. A process as claimed in claim 1, characterized in that the screen has the shape of a conical surface the apex of which is directed upwards and the apex angle of which is in the range from 40 to 140°.

8. A process as claimed in claim 7, characterized in that the apex of the conical surface is situated on the centre line of the water bath and its base is adjacent to the wall of the water bath.

9. A process as claimed in any one or more of the preceding claims, characterized in that the screen is situated below the water level of the water bath.

10. A process as claimed in any one or more of the preceding claims, characterized in that the screen is vibrated.

11. An apparatus for the partial combustion of a carbon-containing fuel with an oxygen-containing gas, which apparatus comprises a reactor which is equipped with a gas outlet at the top and a slag discharge in the bottom, debouching into a water bath, characterized in that the water bath is provided with a sloping screen covering its total horizontal cross section.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