A method and a device for the gasification of solid fuels such as bituminous coal and coke such as bituminous coal, lignite, and biomass, as well as petroleum coke, that are finely ground and mixed with water or oil to make fuel-liquid suspensions, so-called slurries, and their gasification together with an oxidizing medium containing free oxygen by partial oxidation at pressures between atmospheric pressure and 100 bar, and at temperatures between 1200 and 1900°C, in an entrained flow reactor. The method includes the steps of slurry preparation and infed to the reactor, gasification in an entrained flow reactor with cooled reaction chamber contour, partial quenching, waste heat recovery, and wet or dry dust separation, with the crude gas being pretreated so that it can be fed to other technological steps such as crude gas conversion or desulfurization.
METHOD AND DEVICE FOR PRODUCING SYNTHESIS BY PARTIAL OXIDATION OF SLURRIES MADE FROM FUELS CONTAINING ASH WITH PARTIAL QUENCHING AND WASTE HEAT RECOVERY

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a gasification method and a device for implementing the method. The method consists of the process steps of slurry preparation, fuel feed, gasification reaction, partial quenching, gas scrubbing, and partial condensation. Gas scrubbing and partial condensation can be replaced by mechanical dust separation, to produce gases containing CO and H₂ by partial oxidation of powdered fuels containing ash with a gasification medium containing free oxygen, at high temperatures and elevated pressure.

[0003] To achieve long operating times, the pressurized jacket of the gasification reactor has to be protected reliably against the action of crude gas and against the high gasification temperatures of 1200-1900°C. This is done by confining the reaction or gasification chamber with a cooled tubular shield that is hung in the pressurized jacket. The annular gap between tubular shield and pressurized jacket is flushed.

[0004] The fuel as a slurry is brought to the gasification pressure by pump transport and is fed to the head of the reactor through burners. One or more fuels or varieties of coal can be gasified at the same time. The crude gas leaves the gasification chamber together with the liquidified slag at the bottom of the reactor and is then partially cooled to 700°C to 1100°C by injecting water, and is freed of entrained fines. After recovering the waste heat, the scrubbed crude gas is then fed to further treatment steps.

[0005] 2. The Prior Art

[0006] The autothermic entrained flow gasification of solid, liquid, and gaseous fuels has been known in the technology of gas production for years. The ratio of fuel to gasification medium containing oxygen is chosen so that higher carbon compounds are completely cracked for reasons of synthesis gas quality into synthesis gas components such as CO and H₂, and the inorganic components are discharged as molten slag; see J. Carl, P. Fritz, NOELL-KONVERSIONSVERFAHREN, EF-Verlag für Energie und Umwelttechnik GmbH, 1996, p. 33 and p. 73.

[0007] According to various systems used in industry, gasification gas and molten slags can be discharged together from the reaction chamber of the gasification device, as shown in DE 197 131 A1. Either systems with refractory linings or cooled systems are used for the inner confinement of the reaction chamber structure of the gasification system; see German Patent No. DE 4446 803 A1.

[0008] European Patent No. EP 0577 567 B1 and PCT Publication No. WO 96/17904 show a method in which the gasification chamber is confined by a refractory lining. This has the drawback that the refractory lining is loosened by the liquid slag formed during gasification, which leads to rapid wear and high repair costs. This wear process increases with increasing ash content. Thus, such gasification systems have a limited service life before replacing the lining. Also, the gasification temperature and the ash content of the fuel are limited. Feeding in the fuel as a coal-water slurry causes considerable losses of efficiency—see C. Higman and M. van der Burgt, “Gasification”, Verlag ELSEVIER, USA, 2003—which can be prevented or reduced by using oil as a carrier medium or by preheating the coal-water slurry. A quenching or cooling system is also described, with which the hot gasification gas and the liquid slag are carried off together through a conduit that begins at the bottom of the reaction chamber, and are fed into a water bath. This joint discharge of gasification gas and slag can lead to plugging of the conduit and thus to limitation of availability.

[0009] German Patent No. DE 3534041 A1 shows a method in which the gasification media, powdered coal and oxidizing medium containing oxygen, are introduced into the reaction chamber through multiple burners in such a way that the flames are mutually deflected. The gasification gas loaded with powdered dust flows upward and the slag flows downward into a slag-cooling system. As a rule, there is a device above the gasification chamber for indirect cooling utilizing the waste heat. However, because of entrained liquid slag particles, there is the danger of deposition and coating of heat exchanger surfaces, which hinders heat transfer and may lead to plugging of the pipe system and/or erosion. The danger of plugging is counteracted by cooling the hot crude gas with a circulated cooling gas.

[0010] Ch. Higman and M. van der Burgt in “Gasification”, page 124, Verlag Elsevier 2003, describe a method in which the hot gasification gas leaves the gasifier together with the liquid slag and directly enters a waste heat boiler positioned perpendicularly below it, in which the crude gas and the slag are cooled with utilization of the waste heat to produce steam. The slag is collected in a water bath, while the cooled crude gas leaves the waste heat boiler from the side. A series of drawbacks detract from the advantage of waste heat recovery by this system, such as the formation of deposits on the heat exchanger tubes, which lead to hindrance of heat transfer and to corrosion and erosion, and thus to lack of availability.

[0011] Chinese Patent No. CN 200 4200 200 7 1 describes a “Solid Pulverized Fuel Gasifier”, in which the powdered coal is fed in pneumatically and gasification gas and liquefied slag are introduced into a water bath through a central pipe for further cooling. This central discharge in the central pipe mentioned is susceptible to plugging that interferes with the overall operation, and reduces the availability of the entire system.

SUMMARY OF THE INVENTION

[0012] It is therefore an object of the invention to provide a gasification method that takes into account the different ash contents of fuels and has high availability, with reliable operation.

[0013] This task is accomplished by a gasification method for the gasification of solid fuels containing ash with an oxidizing medium containing oxygen, in a gasification chamber designed as an entrained flow reactor, at pressures between atmospheric pressure and 100 bar, in which the reaction chamber contour is confined by a cooling system, with the pressure in the cooling system always being chosen.
to be higher than the pressure in the reaction chamber. The method is distinguished by the following features:

[0014] The fuel, e.g. bituminous coal, bituminous coke and lignite coke, as well as biomass coke and/or petroleum coke and/or their mixtures, are pulverized to a grain size of \( <500 \mu m \), preferably \( <200 \mu m \), and are mixed to make a fuel in-water or fuel-in-oil suspension, a so-called slurry, by adding liquids such as water or oil. Stable solids concentrations of up to 70 wt. % are achieved when using water as the carrier medium with added surfactants. These are brought to the desired gasification pressure of up to a maximum of 100 bar by means of suitable pumps, and are fed for the gasification reaction through suitable burners that are attached at the head of the gasification reactor. The fuel concentration in the slurry and the amount of flowing slurry are monitored, measured, and regulated by measurement devices, control devices, and monitors. An oxidizing medium containing free oxygen is fed to the burner at the same time, and the fuel is converted into crude synthesis gas by partial oxidation. The gasification takes place at temperatures between 1,200°C and 1,900°C at pressures up to 100 bar. The reactor is equipped with a cooling shield that consists of water-cooled pipes welded gas-tight.

[0015] The hot crude synthesis gas leaves the gasification chamber together with the liquid slag formed from the fuel ash, and arrives at a chamber perpendicularly under it, in which partial quenching occurs by injecting water or by feeding in a cold gas, whereby it is cooled to temperatures between 700°C and 1,100°C. At this temperature, the entrained liquid slag has been cooled to the extent that it can no longer adhere to the metallic surfaces. The crude gas cooled to temperatures of 700°C and 1,100°C then arrives at a waste heat boiler together with the likewise cooled solid slag, to utilize the sensible heat for steam production. This partial quenching or partial cooling prevents or sharply reduces the risk of slag caking on the waste heat cooling pipes. The water or recycled gas condensate needed for the partial quenching is fed in through nozzles that are located directly on the jacket. The cooled slag is collected in a water bath located at the bottom of the waste heat boiler. The crude gas, cooled to 200°C-300°C, leaves the waste heat boiler at the side and reaches a crude gas scrubber, suitably a Venturi scrubber. The entrained dust is thereby removed down to a grain size of about 20 μm. This degree of purity is still inadequate for carrying out subsequent catalytic processes, for example crude gas conversion. It also has to be considered that salt mists are also entrained in the crude gas, which have detached from the powderied fuel during gasification and are carried off with the crude gas. To remove both the fine dust <20 μm and the salt mists, the scrubbed crude gas is fed to a condensation step in which the crude gas is chilled indirectly to about 5°C to 10°C. Water is thereby condensed from the crude gas saturated with water vapor, which absorbs the described fine dust and salt particles. The condensed water containing the dust and salt particles is separated in a following separator. The crude gas purified in this way can then be fed directly, for example, to a crude gas converter or desulfurization system.

[0016] Instead of the scrubbing and condensation steps, a mechanical dust separator can be provided that operates at 200°C to 300°C, for which centrifugal separators or filter systems can be used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Other objects and features of the present invention will become apparent from the following detailed description considered in connection with the accompanying drawings. It is to be understood, however, that the drawings are designed as an illustration only and not as a definition of the limits of the invention.

[0018] In the drawings, wherein similar reference characters denote similar elements throughout the several views:

[0019] FIG. 1 shows a block diagram of the technology;

[0020] FIG. 2 shows a gasification reactor with partial quenching and perpendicularly arranged waste heat boiler, and

[0021] FIG. 3 shows a gasification reactor with partial quenching and adjacent waste heat boiler.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] 320 tons/hour of bituminous coal with a composition of

| C    | 71.5 wt. % |
| H    | 4.2 wt. %  |
| O    | 9.1 wt. %  |
| N    | 0.7 wt. %  |
| S    | 1.5 wt. %  |
| Cl   | 0.03 wt. % |

an ash content of 11.5 wt. %, and a moisture content of 7.8 wt. %, is to be gasified at a pressure of 40 bar. The calorific value of the coal is 25,600 kJ/kg. The gasification takes place at 1,450°C. 250,000 m³ (standard)/h of oxygen is needed for the gasification. The coal is first fed to a stator-of-the-art grinder in which it is pulverized to a grain size range between 0 and 200 μm, and is then mixed in a special system 1 according to FIG. 1 with water with added surfactants to make a stable coal dust in water suspension, the so-called slurry. The solids concentration in this slurry is 63 wt. %, and the amount of slurry is 485 tons/hour. The slurry is brought to the desired gasification pressure of 100 bar by means of a pump suitable for pumping solid-liquid suspensions, and is fed to the burner of the gasification reactor 2 of FIG. 1 through the supply line 1.1, with the amount being monitored, measured, and regulated. To conserve oxygen, the slurry can be preheated up to 400°C, depending on the gasification pressure, prior to being fed into the gasification reactor 2.

[0023] FIGS. 2 and 3 show the gasification reactor. The slurry flowing to the gasification reactor through the feed line 1.1 at 465 tons/hour is subjected to partial oxidation at 1450°C, along with the 254,000 m³ (standard)/hour of oxygen flowing to the gasification chamber 2.3 through the line 2.1, with 555,000 m³ (standard)/hour of crude gas being formed with the following composition:

| H₂   | 18.5 vol. % |
| CO   | 70.5 vol. % |
The gasification chamber 2.3 is confined by a cooling shield 2.4 that consists of a water-cooled tube system welded gas-tight. The crude gas together with the liquid slag flows through the outlet 2.5 into the chamber 3.1 for partial quenching/partial cooling of the crude gas to temperatures of $700^\circ$C. At this temperature, along with the crude gas, the slag is also cooled to such an extent that it cannot be deposited in the pipes 4.1 of the waste heat boiler that follows according to FIG. 1. The steam generated in the waste heat boiler 4 is utilized in the process to preheat the oxidizing medium containing oxygen or as a gasification moderator to preheat the slurry. The slag is collected in a water bath 4.2 located at the bottom of the waste heat boiler and is discharged through 4.3. The crude gas leaves the waste heat boiler through 4.4 and arrives at crude gas scrubber 5 according to FIG. 1. Waste heat boiler 4, however, can be located according to FIG. 3 directly beneath gasification reactor 2 and partial quencher 3, but also, as shown in FIG. 4, beside it. In this case, there is a slag discharge 4.3 beneath partial quencher 3 and also one below waste heat boiler 4.6. The crude gas leaving waste heat boiler 4 through outlet 4.4 then arrives at the crude gas scrubber 5 according to FIG. 1, which is an adjustable Venturi scrubber to which is fed about 100 m$^3$/h of wash water. The wash water is freed of absorbed solids in the usual way and is fed again to the Venturi scrubber. The wash water can be preheated in order to wet the crude gas further at the same time as the washing. To remove fine dust <20 μm in size and salt mist not separated in the Venturi scrubber, the water-washed crude gas is subjected to partial condensation 6 according to FIG. 1, with the crude gas being chilled indirectly to about 5-10°C. The finest dust and salt particles are taken up by the water vapor condensing during the chilling and thus removed from the crude gas. The crude gas cleansed of solids then has the following composition:

<table>
<thead>
<tr>
<th></th>
<th>13.4 vol. %</th>
<th>51.4 vol. %</th>
<th>4.5 vol. %</th>
<th>1.5 vol. %</th>
<th>0.0022 vol. %</th>
<th>0.0002 vol. %</th>
<th>0.36 vol. %</th>
<th>0.05 vol. %</th>
<th>37.30 vol. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{H}_2$</td>
<td>CO</td>
<td>$\text{CO}_2$</td>
<td>$\text{N}_2$</td>
<td>$\text{NH}_3$</td>
<td>$\text{HCN}$</td>
<td>$\text{H}_2S$</td>
<td>$\text{CO}_2$</td>
<td>$\text{COS}$</td>
<td>$\text{H}_2O$</td>
</tr>
</tbody>
</table>

What is claimed is:

1. A method for the gasification of fuels such as bituminous coals and cokes such as bituminous, lignite, biomass, and petroleum coke in the entrained flow with an oxidizing medium containing free oxygen, the method comprising the following steps:

- slurring a pulverized fuel with a grain size <200 μm with water with added surfactant, to obtain a fuel-in-water slurry with a solids concentration of 40-70 wt. %;
- bringing the slurred fuel to a gasification pressure of 100 bar by pumping, for which the slurry is preheated to temperatures up to 400°C;
- feeding the fuel to the reactor through a supply pipe together with an oxidizing medium containing free oxygen;
- subjecting the fuel to partial oxidation in the reaction chamber at pressures between atmospheric pressure and 100 bar, the reaction chamber having a contour confined by a cooling shield;
- melting ash of the fuel;
- transferring the melted ash through a discharge device to a quenching chamber of a quenching cooler along with hot crude gas;
- partially quenching the crude gas in the quenching cooler with cooling of the crude gas to temperatures between 700 and 1100°C.
cooling the partially quenched crude gas in a waste heat boiler to temperatures between 150 and 400°C, with generation of steam;

subjecting the cooled crude gas to a crude gas scrubber and partial condensation, or to dry mechanical dust separation by centrifugal force or filtration, to separate entrained dust; and

sending the cooled gas freed of dust to additional treatment steps.

2. A method pursuant to claim 1, wherein a crude gas scrubber is used, and the crude gas scrubber is a single- or multiple-stage Venturi scrubber.

3. A method pursuant to claim 2, wherein the Venturi scrubber is supplied with fresh water or recycled condensates that result from the cooling of the gas.

4. A method pursuant to claim 1, wherein the waste heat boiler is operated at temperatures of 700 to 1,100°C.

5. A method pursuant to claim 2, wherein the crude gas scrubbing takes place at temperatures of 150 to 300°C.

6. A method pursuant to claim 2, wherein the Venturi scrubber is supplied with circulated water or recycled condensate.

7. A method pursuant to claim 1, wherein the fuel is supplied to the reactor as a fuel-in-water slurry.

8. A method pursuant to claim 1, wherein the fuel is supplied to the gasification reactor through one or more burners.

9. A method pursuant to claim 1, wherein granulated slag from the quenching cooler is discharged through one or more outlets from the quenching cooler.

10. A method pursuant to claim 1, wherein the partially quenched gas leaves the quenching cooler through one or more gas outlets.

11. A method pursuant to claim 1, wherein one or more varieties of coal are gasified at the same time.

12. A method pursuant to claim 1, wherein the amount of slurry in the supply pipe is measured, monitored, and regulated.

13. Device for gasification of fuels such as bituminous coals and cokes such as bituminous, lignite, biomass, and petroleum coke in the entrained flow with an oxidizing medium containing free oxygen, comprising:

   a system for producing and feeding slurry;

   a reactor for the gasification of supplied powdered fuel with an oxidizing medium containing free oxygen, comprising a supply pipe for the slurred fuel and a line for the oxidizing medium, burners for feeding the slurred fuel and oxidizing medium into a reaction chamber of the reactor, said reaction chamber having a cooling shield consisting of water-cooled pipes welded gas-tight and a discharge device;

   a quenching cooler with no internals connected to the reactor via the outlet device, the quenching cooler having nozzles arranged in one or more nozzle rings through which is sprayed water for partial quenching, said nozzles being integrally incorporated in an inner jacket;

   a waste heat boiler following the quenching cooler; and

   equipment for purifying the gasified fuel.

14. A device pursuant to claim 13, wherein a reaction chamber of the quenching cooler is connected directly to the waste heat boiler, in which heat of the crude gas is utilized through tubes to produce steam, and wherein there are discharge openings in a bottom of the waste heat boiler for crude gas and for slag withdrawal with a water bath.

15. A device pursuant to claim 13, further comprising a crude gas scrubber and a partial condensation system following the crude gas scrubber for purification.

16. A device pursuant to claim 15, wherein the crude gas scrubber is a single- or multiple-stage Venturi scrubber.

17. A device pursuant to claim 13, further comprising a mechanical dry dust separator for gas purification.

18. A device pursuant to claim 15, wherein there are further gas treatment stages connected in line after the water scrubber and partial condenser or the mechanical dry dust separator.

19. A device for gasification of fuels such as bituminous coals and cokes such as bituminous, lignite, biomass, and petroleum coke in the entrained flow with an oxidizing medium containing free oxygen, comprising:

   a system for producing and feeding slurry;

   a reactor for gasification of supplied fuel dust with an oxidizing medium containing free oxygen, the reactor comprising a supply pipe for receiving slurred fuel and a line for the oxidizing medium, said slurred fuel and oxidizing medium being fed by burners into a reaction chamber of the reactor, said reaction chamber comprising a cooling shield made of water-cooled pipes welded gas-tight and a discharge device;

   a quenching cooler connected to the discharge device;

   a waste heat boiler connected to the quenching cooler via a transfer line for receiving partially cooled crude gas, said boiler being equipped with boiler tubes and utilizing heat of the crude gas to produce steam;

   a crude gas scrubber and a partial condensation system following the crude gas scrubber, or a mechanical filtration dust separator.

20. A device pursuant to claim 19, further comprising water baths in both the quenching cooler and the waste heat boiler, in which water baths cooled slag is collected.

21. A device pursuant to claim 19, further comprising devices for discharging slag on both the quenching cooler and the waste heat boiler.

* * * * *