

BIOMASS SYNGAS PURIFICATION PROCESS UNDER POSITIVE PRESSURE FOR PRODUCING OIL AND SYSTEM CONFIGURATION THEREOF

FIELD OF THE INVENTION

[0001] The invention relates to a method and an apparatus for purifying biomass syngas under a positive pressure for producing oil.

BACKGROUND OF THE INVENTION

[0002] With the dwindling reserve of the fossil fuel, the biomass of the renewable clean energy has been paid more and more attention and been developed fast. Gas production and oil production using the biomass has been an important research project in the field of the new energy development.

[0003] Like the coal gas production, the biomass gas production requires purification processes of cooling and washing. Currently, researches on the method for biomass gasification have gained a large amount of results, whereas relatively few researches on the purification of the biomass syngas, mainly in reference to the conventional method for cooling and washing the coal gas, have been carried out. However, it is improper to copy the conventional process for preliminarily cooling the coal gas without taking consideration of the practical situation that an outlet temperature of the biomass syngas is much higher than an outlet temperature of the coal gas, that is, a temperature of the crude coal gas from a carbonization furnace is at 650°C while a temperature of the syngas at the outlet of the gasifier of the process of the invention is higher than 1000°C. Thus, it is desired to develop an innovative cooling method for biomass syngas.

[0004] Conventional means for preliminary cooling the coal gas include: indirect

preliminary cooling, direct preliminary cooling, and indirect-direct preliminary cooling. The preliminary cooling mainly means that the coal gas is cooled to a temperature of between 22 and 35°C after flowing out of the carbonization furnace and before entering an electro tar precipitator.

[0005] The indirect preliminary cooling is a process in which the coal gas does not directly contact with a cooling medium, heat transfer but no mass transfer occurs between the two phases. The indirect preliminary cooling has good cooling and purification effects.

[0006] The direct preliminary cooling is a process including spraying ammonia solution into the coal gas to enable the ammonia solution to directly contact with the coal gas so that both the heat transfer and the mass transfer occur. Compared with the indirect preliminary cooling, the direct preliminary cooling features high cooling efficiency of the coal gas, small resistance, low price in devices, and large power consumption.

[0007] The indirect-direct preliminary cooling is a combined process includes introducing the coal gas to an indirect cooler and a direct cooler, respectively, and has advantages of both the direct preliminary cooling and the indirect preliminary cooling.

[0008] Methods for removing dust from coal gas include: precipitation, filter, cyclone, electric precipitation, water washing, and dust removal by Venturi scrubber. Different dust removal methods vary in the dust removal effect and the resistance consumption.

[0009] A primary device for removing the tar from the coal gas is an electro tar precipitator.

[0010] Characteristics of syngas produced from different raw materials and by different gasification processes are almost the same. However, targeted process method and system configuration should be adopted to ensure advanced purification target and economy target.

[0011] Characterized in complicate system, long procedure, high energy consumption,

low efficiency and stability, and being uneconomic, the conventional methods for coal gas purification must be optimized and developed when it is applied to treat the biomass syngas.

[0012] The technical solution of the invention forms as a result of extensive researches on the method for cooling and gasification of the syngas by combining the high-temperature gasification process of the biomass with the chemical and physical properties of the syngas.

SUMMARY OF THE INVENTION

[0013] It is one objective of the invention to provide a method and an apparatus for purifying biomass syngas under a positive pressure for producing oil. By adopting optimized and targeted process scheme and procedure design, by reasonably configuring process devices, and by properly controlling process parameters, problems are solved that the conventional coal chemical industrial purification method has a complicated system, long procedure, high energy consumption, low efficiency and stability, and is uneconomic and poorly targeted, so that the technology and the economy are unified.

[0014] Technical solution of the invention is developed based on characteristics of the high-temperature plasma gasification process in the biomass fixed bed and the syngas (having a temperature of between 1000 and 1100°C, a dust content of below 20 g/Nm³, and a tar content of below 3 g/Nm³) and according to the cooling and purification process of coal gas. A method for purifying biomass syngas under a positive pressure for producing oil, the method comprises: aerating a high-temperature pyrolysis gasifier by using an oxidation fan; introducing high-temperature syngas produced in the high-temperature pyrolysis gasifier through a high-temperature water-cooling flue to a water-cooling quench tower, where water is sprayed into the high-temperature syngas for quenching a part of slag; introducing the syngas from the water-cooling quench tower to a

waste heat boiler of a water-tube type and a waste heat boiler of a heat-tube type, where waste heat is recovered in two sections at two pressures, by-products including middle pressure vapor and low pressure vapor are produced and supplied to external devices, and a heavy tar is condensed and recovered by the waste heat boiler of the heat-tube type; introducing the syngas from the waste heat boiler of the heat-tube type to a Venturi scrubber in the absence of a filler for washing the syngas and removing dust; introducing the syngas from the Venturi scrubber to a wet electric dust collector for further removing the dust and a tar for purification so that both a dust content and a tar content in the syngas are $<10 \text{ mg/Nm}^3$, a temperature of the syngas is $<45^\circ\text{C}$, and a sensible heat recovery is higher than 80%; and transporting qualified syngas to a wet gas tank for storage or to a downstream process for use.

[0015] In the technical solution, the high-temperature syngas produced in the high-temperature pyrolysis gasifier has the temperature of between 1000 and 1100°C , the dust content of lower than 20 g/Nm^3 , and the tar content of lower than 3 g/Nm^3 . The high-temperature syngas is introduced out of the gasifier via a top thereof, through the high-temperature water-cooling flue, and into the water-cooling quench tower, where water is sprayed to decrease a temperature of the syngas to be $800 \pm 20^\circ\text{C}$ and to condense the slag. The syngas is then introduced to the waste heat boiler of the water-tube type for recovering middle temperature waste heat; and the middle pressure vapor produced therein is supplied to the external devices. The syngas flowing out of the waste heat boiler of the water-tube type has a temperature of $450 \pm 20^\circ\text{C}$. The syngas is then transported to the waste heat boiler of the heat-tube type for recovering low temperature waste heat; and the low pressure vapor produced therein is supplied to the external devices. The syngas is cooled in the waste heat boiler of the heat-tube type, and the heavy tar is separated simultaneously and is collected by a chute. The temperature of the syngas flowing out of the waste heat boiler of the heat-tube type is decreased to $200 \pm 10^\circ\text{C}$. The syngas is then transported to the Venturi scrubber in the absence of the filler to wash the

syngas, remove the dust, and further decrease the temperature of the syngas, so that a majority of the dust, tar drops, and water soluble gas enter a washing liquid and are removed. The temperature of the syngas after washing is $45 \pm 2^{\circ}\text{C}$. The syngas is transported to the wet electric dust collector to further remove the dust and the tar therein so that the syngas has both the dust content and the tar content of $< 10 \text{ mg/Nm}^3$, the temperature of $< 45^{\circ}\text{C}$, and the sensible heat recovery of higher than 80%. The qualified syngas is transported to the wet gas tank for storage or is supplied to the downstream process for use. A flare is in parallel connection with the wet gas tank for combusting waste gas.

[0016] As an improvement of the invention, the oxidation fan is employed to blast air and provide the positive pressure, thereby deleting a coal gas blower. By increasing an outlet pressure of the oxidation fan, an outlet pressure of the high-temperature pyrolysis gasifier overcomes a resistance of a washing system and an inlet pressure of the wet gas tank still maintains at between 4 and 6 KPa, whereby enabling the water-cooling quench tower, the waste heat boiler of the water-tube type, the waste heat boiler of the heat-tube type, the Venturi scrubber in the absence of the filler, the wet electric dust collector, and the wet gas tank to work at the positive pressure, preventing the atmosphere from penetrating into the above devices, and decreasing the possibility of gas explosion.

[0017] As an improvement of the invention, both the high-temperature water-cooling flue and the water-cooling quench tower adopt membrane water-cooling pipe structures, thereby decreasing the weight thereof, avoiding a problem of abscission of fire-proof materials, and improving the operation reliability. The high-temperature water-cooling flue, the water-cooling quench tower, and the waste heat boiler are in series connection to form a water circulating system, so that the water cooling problem of the circulating water is solved, and a full recovery of the heat energy is realized.

[0018] As an improvement of the invention, water is sprayed into the high-temperature

syngas in the water-cooling quench tower for decreasing the temperature of the syngas to $800 \pm 20^{\circ}\text{C}$ and condensing the slag in the syngas; and the slag is discharged from a tower bottom. Thus, heating surfaces of the waste heat boilers are prevented from slag pollution, and stability of heat exchange performance of the waste heat boilers is ensured.

[0019] As an improvement of the invention, the waste heat boiler includes a high temperature section and a lower temperature section. The high temperature section employs the waste heat boiler of the water-tube type, and the lower temperature section employs the waste heat boiler of the heat-tube type. The temperature of the syngas at the outlet of the waste heat boiler of the water-tube type is $450 \pm 20^{\circ}\text{C}$, which is higher than a condensation point of the heavy tar, thereby avoiding the condensation of the tar. A design pressure in the waste heat boiler of the water-tube type is equal to or larger than 1.6 megapascal, thereby improving the temperature quality of the vapor and satisfying requirements of corresponding chemical vapor.

[0020] A temperature of the syngas at the outlet of the waste heat boiler of the heat-tube type is controlled at less than 200°C to condense the heavy tar in this section and to collect the heavy tar by the chute. The low temperature section employs the waste heat boiler of the heat-tube type for improving the heat exchange effect. A design pressure in the waste heat boiler of the heat-tube type is 0.5 megapascal, and the low pressure vapor produced therein is supplied to the wet electric dust collector for sweeping.

[0021] The biomass syngas has both relatively low dust content and tar content. The Venturi scrubber (in the absence of the filler) is configured for preliminary dust removal, not only are purposes of dust removal and temperature decrease are realized, but also harmful gases, including H_2S , NH_3 , and HCN , are removed by washing.

[0022] The wet electric dust collector is configured in the rear part of the process flow for ensuring control targets of the dust removal and the tar removal.

[0023] Compared with the prior art, the invention solves the following problems and has

obvious advantages.

[0024] The method is applicable to the adiabatic high-temperature gasifier, and technical problems are solved that the gasifier in water cooling or product gas cooling has a complicate structure and a large size, slag easily aggregates on the wall of the gasifier, scale easily forms in the water side, the energy consumption and the power consumption are high. While the gasification stability is improved, production costs in the main gasification device are saved.

[0025] The high-temperature water-cooling flue is employed, so that problems are solved that the adiabatic flue is cumbersome, expanded, and is difficult for hanging, a liner thereof easily collapses, and a service life thereof is short.

[0026] Quenching process is performed out of the gasifier by spraying water, so that the gasification process is not affected. The quenching degree is partially controlled, thus, both the slag condensation effect and the thermal efficiency of the system are improved.

[0027] The configuration of the two sections of waste heat boilers under two pressures reaches a centralized collection of the heavy tar, gradual waste heat recovery, and improvement of the heat efficiency of the devices.

[0028] The Venturi scrubber in the absence of the filler is used to wash the gas and remove the dust, and the wet electric dust collector is used to further remove the tar and the dust, thereby realizing the purification target by removing the dust and the tar gradually.

[0029] The invention has simple system, smooth process, low energy consumption, high efficiency, security and stability, and high economic benefit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. 1 is a flow chart of a method for purifying biomass syngas under a positive pressure for producing oil of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0031] A method for purifying biomass syngas under a positive pressure for producing oil is further illustrated herein below combined with the drawing.

[0032] As shown in FIG. 1, an apparatus for conducting the main process of the technical solution comprises: a high-temperature water-cooling flue 1, a water-cooling quench tower 2, a waste heat boiler of a water-tube type 3, a waste heat boiler of a heat-tube type 4, a Venturi scrubber 5, a wet electric dust collector 6, a wet gas tank 7, and a flare 8.

[0033] Parameters and process flow of the invention are as follows: an oxidation fan is employed to blast air to the high-temperature pyrolysis gasifier. High-temperature syngas produced in the high-temperature pyrolysis gasifier having a temperature of between 1000 and 1100°C, a dust content of lower than 20g/Nm³, and a tar content of lower than 3g/Nm³ is introduced out of the gasifier via a top thereof, through the high-temperature water-cooling flue 1, and into the water-cooling quench tower 2, where water is sprayed to decrease a temperature of the syngas to be 800 ± 20°C and to condense the slag. The syngas is then introduced to the waste heat boiler of the water-tube type 3 for recovering middle temperature waste heat. Middle pressure vapor produced therein is supplied to external devices. The syngas flowing out of the waste heat boiler of the water-tube type 3 has a temperature of 450 ± 20°C. The syngas is then transported to the waste heat boiler of the heat-tube type 4 for recovering low temperature waste heat; and low pressure vapor produced therein is supplied to the external devices. The syngas is cooled in the waste heat boiler of the heat-tube type 4, and a heavy tar is separated simultaneously and is collected by a chute. The temperature of the syngas flowing out of the waste heat boiler of the heat-tube type 4 is decreased to 200°C below. The syngas is then transported to the

Venturi scrubber **5** (in the absence of the filler) to wash the syngas, remove the dust, and further decrease the temperature of the syngas, so that a majority of the dust, tar drops, and water soluble gas enter a washing liquid and are removed. The temperature of the syngas after washing is $< 45^{\circ}\text{C}$. The syngas is thereafter transported to the wet electric dust collector **6** to further remove the dust and the tar. The syngas after the above cooling and purification treatments has both the dust content and the tar content of $< 10\text{mg}/\text{Nm}^3$, the temperature of $< 45^{\circ}\text{C}$, and a sensible heat recovery of higher than 80%, which completely satisfies the gas requirement of subsequent processes. The qualified syngas is then transported to the wet gas tank **7** for storage or is supplied to the downstream process for use. The flare **8** is in parallel connection with the wet gas tank **7** and is an important device to combust waste gas when the system is started and the composition of the syngas is excessive.

[0034] The main process flow of the cooling and washing of the syngas under positive pressures and related devices are described in the above. In addition to auxiliary systems like a water spraying system for the quench tower, a water feeding system for the two sections of waste heat boiler, a water circulating system for the Venturi scrubber, a water flushing system for the wet electric dust collector, and a water sealing system for the wet gas tank, some standard or nonstandard devices are also provided. The standard or nonstandard devices form individual subsystems via pipes and valves, and serve related devices, so that the whole process flow of the cooling and washing of the biomass syngas is realized.

CLAIMS

1. A method for purifying biomass syngas under a positive pressure for producing oil, the method comprising:
aerating a high-temperature pyrolysis gasifier using an oxidation fan;
introducing high-temperature syngas produced in the high-temperature pyrolysis gasifier through a high-temperature water-cooling flue to a water-cooling quench tower, where water is sprayed into the high-temperature syngas for quenching a part of slag;
introducing the syngas from the water-cooling quench tower to a waste heat boiler of a water-tube type and a waste heat boiler of a heat-tube type, where waste heat is recovered in two sections at two pressures, middle pressure vapor and low pressure vapor are produced and supplied to external devices, and a heavy tar is condensed and recovered by the waste heat boiler of the heat-tube type;
introducing the syngas from the waste heat boiler of the heat-tube type to a Venturi scrubber in the absence of a filler for washing the syngas and removing dust;
introducing the syngas from the Venturi scrubber to a wet electric dust collector for further removing the dust and a tar for purification so that both a dust content and a tar content in the syngas are $<10 \text{ mg/Nm}^3$, a temperature of the syngas is $<45^\circ\text{C}$, and a sensible heat recovery is higher than 80%; and
transporting qualified syngas to a wet gas tank for storage or to a downstream process for use.
2. The method of claim 1, **characterized in that**
the high-temperature syngas produced in the high-temperature pyrolysis

gasifier has a temperature of between 1000 and 1100°C, a dust content of lower than 20g/Nm³, and a tar content of lower than 3g/Nm³;

the high-temperature syngas is introduced out of the gasifier via a top thereof, through the high-temperature water-cooling flue (1), and into the water-cooling quench tower (2), where water is sprayed to decrease a temperature of the syngas to be $800 \pm 20^{\circ}\text{C}$ and to condense the slag;

the syngas is introduced to the waste heat boiler of the water-tube type (3) for recovering middle temperature waste heat; the middle pressure vapor produced therein is supplied to the external devices; the syngas flowing out of the waste heat boiler of the water-tube type has a temperature of $450 \pm 20^{\circ}\text{C}$;

the syngas is then transported to the waste heat boiler of the heat-tube type (4) for recovering low temperature waste heat; the low pressure vapor produced therein is supplied to the external devices; the syngas is cooled in the waste heat boiler of the heat-tube type (4), and the heavy tar is separated simultaneously and is collected by a chute; the temperature of the syngas flowing out of the waste heat boiler of the heat-tube type is decreased to $200 \pm 10^{\circ}\text{C}$;

the syngas is then transported to the Venturi scrubber (5) in the absence of the filler to wash the syngas, remove the dust, and further decrease the temperature of the syngas, so that a majority of the dust, tar drops, and water soluble gas enter a washing liquid and are removed;

the temperature of the syngas after washing is $45 \pm 2^{\circ}\text{C}$; the syngas is transported to the wet electric dust collector (6) to further remove the dust and the tar therein so that the syngas has both the dust content and the tar content of $< 10\text{mg}/\text{Nm}^3$, the temperature of $< 45^{\circ}\text{C}$, and the sensible heat recovery of higher than 80%;

the qualified syngas is transported to the wet gas tank (7) for storage or is

supplied to the downstream process for use; and

a flare (8) is in parallel connection with the wet gas tank (7) for combusting waste gas.

3. The method of claim 2, **characterized in that** both the high-temperature water-cooling flue (1) and the water-cooling quench tower (2) adopt membrane water-cooling pipe structures.
4. The method of claim 2, **characterized in that** a design pressure in the waste heat boiler of the water-tube type (3) is equal to or larger than 1.6 megapascal; and a temperature of the syngas at an outlet of the waste heat boiler of the water-tube type (3) is $450 \pm 20^{\circ}\text{C}$.
5. The method of claim 2, **characterized in that** a temperature of the syngas at the outlet of the waste heat boiler of the heat-tube type (4) is controlled at less than 200°C to condense the heavy tar in this section and to collect the heavy tar by the chute.
6. The method of claim 2, **characterized in that** a design pressure in the waste heat boiler of the heat-tube type (4) is 0.5 megapascal; and the low pressure vapor produced therein is supplied to the wet electric dust collector (6) for sweeping.
7. The method of claim 1, **characterized in that** an outlet pressure of the oxidation fan is capable of ensuring that an outlet pressure of the high-temperature pyrolysis

gasifier overcomes a resistance of a washing system and an inlet pressure of the wet gas tank (7) maintains at between 4 and 6 KPa, whereby enabling the water-cooling quench tower (2), the waste heat boiler of the water-tube type (3), the waste heat boiler of the heat-tube type (4), the Venturi scrubber (5) (in the absence of the filler), the wet electric dust collector (6), and the wet gas tank (7) to work at the positive pressure.