METHOD AND DEVICE FOR PRODUCING COKE FROM NONCAKING COALS

Abstract: The invention relates to coke production in general and specifically to methods and devices for the production of metallurgical coke from noncaking coals. The method comprises metering, crushing and mixing of coal, an adhesion agent, and an organic waste component to produce uniform feedstock and subsequent heating of the feedstock, wherein as the adhesion agent are used high boiling point products of plastic waste pyrolysis, which are added to the feedstock in an amount of 15% to 20% of the total feedstock volume and wherein the feedstock is heated in the temperature range 250°C to 1100°C. The device comprises a fire-resistant coking chamber; heating ducts; burners; means for charging the material to be coked; a coke discharging means, wherein the device comprises a heating tank provided with a charging hole for charging plastic waste, organic waste, and catalysts; and with a flight conveyor for removing undissolved residues from said tank.
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METHOD AND DEVICE FOR PRODUCING COKE FROM NONCAKING COALS

The invention relates to coke production in general and specifically to methods and devices for the production of metallurgical coke from noncaking coals.

At present, the most wide-spread process is production of coke in multi-chamber ovens with periodic charging and discharging, using the feedstock essentially consisting of the well-caking coals, such as rich coals, coking coals and leaned caking coals. However, the problem that resources of such coals are limited is becoming increasingly urgent. At that, use of noncaking coals, such as long-flame coals, brown coals, lean coals and gas coals as an addition to the feedstock, does not solve the problem of shortage of raw materials for the coke production industry. Besides, addition of long-flame coals and gas coals to the feedstock results in reduction of the coke yield due to an increased yield of the volatile products of coking. With the existing technology comprising the steps of periodic charging of the feedstock and discharging of the coke, this also results in significant reduction of the output of an oven and in an increased cost of the produced coke while the quality of the produced coke is lower. Increase of content of high-metamorphized coals, such as lean coals, results in a significant reduction of the strength of the produced coke due to a low reactivity of such coals.

At the same time, the resources of brown coals and long-flame coals are several times those of caking coals. Besides, the cost of said brown coals and long-flame coals is significantly lower than the cost of caking coals because they occur at shallow depths and are extracted by opencast mining. However, production of metallurgical coke from brown coals, long-flame coals, or lean coals, which belong to the group of noncaking coals, is impossible with the conventional processes because the products of pyrolysis of said coals do not contain liquid nonvolatile elements, which ensure formation of a plastic coal mass and formation of a solid coke body. Therefore, widespread use of brown coals, long-flame coals and lean coals, all of which are noncaking coals, in coke production is
hindered because there is no process by which to produce coke from such coals that would ensure the desired quality.

In the art there are known additions to the feedstock for coking made of production waste, which additions improve coking properties of the feedstock and make it possible to increase content of a leaned coal introduced as an addition while maintaining satisfactory characteristics of the coke. As such additions, benzene separation tar; fuses (heavy coal-tar products), fuel oil, coal tar, and coal-tar pitch may be used. Coal tar and coal-tar pitch have the best coking properties. These additions are, however, valuable marketable products, and the quantity of a benzene separation tar and fuses formed is insignificant and insufficient for the production needs for caking additions, and, therefore, their use to improve the coking properties of the feedstock is not economical. Also, in the art there are known the processes of liquefying low-metamorphized coals with a special mixture of organic solvents at a temperature of up to 450°C in the presence of hydrogen and catalysts. However, due to a low boiling point of the solvents, the process should be performed intermittently and under a pressure of up to 25 MPa. In this case, the costs of producing liquid products from coal exceed the costs of producing their analogues from oil.

It is known in the art that heat treatment of a mixture of plastic waste in the presence of catalysts at the temperature 280°C to 350°C results in a pyrolytic process in plastic waste and a chemical interaction between the products of pyrolysis to form medium-molecular-weight tar-like products of an aromatic structure. It is also known in the art that said products, which are a chemical analogue of the primary tar of the coal pyrolysis, may also act as liquid nonvolatile components of a plastic-coal mass and ensure formation of a solid-coke body.

The Russian Federation patent No. 2144555 describes a method and device for producing coke, wherein the device for carrying out the method of producing coke comprises a fire-resistant coking chamber, heating ducts, burners, means for charging the material to be coked, as well as a means for discharging the coke. Said heating ducts are formed by an outer wall and an inner wall of said chamber and by the space between the
walls in which the material to be coked is placed. Also, the fire-resistant chamber is provided with means functioning as a protective casing and making it possible to produce an excess pressure in the chamber during the coking process. The means for charging the material to be coked comprise a hopper with a gate; and a piston pusher. The means for discharging the coke comprises a hopper with a gate.

The principal disadvantages of said device for producing coke are the impossibility to employ the device of such design for producing coke from noncaking coals and also the impossibility to provide a safe and environment-friendly production of coke because of the untight design of the device.

The closest prior art for the present invention is a method of producing coke from noncaking coals described in an USSR Inventor's Certificate No. 920066, the method comprises metering, crushing and mixing of coal, an adhesion agent, and an organic waste to produce a uniform feedstock and subsequent heating of the feedstock. A coking process is carried out under a pressure of above 600 kg/cm². As the adhesive agents, are used the high boiling point and asphalt-containing tar and oil products, as well as the coal tar emulsion.

The principal disadvantage of said method of producing coke from noncaking coals is that it is not possible to obtain products of high quality, in particular, to ensure the desired strength of the coke produced. Another disadvantage of this method is the technological complexity of providing the conditions necessary to ensure reactions resulting in formation of a solid-coke body.

The objective of the present invention is to provide a method of and a device for producing coke from noncaking coals, which, due to its simplicity and effectiveness of the process and design, will ensure the possibility of an economic, safe and environment-friendly coke production from noncaking coals, and at the same time ensure high quality of the obtained product.

This objective is achieved through a method for producing coke from noncaking coals, the method comprising metering, crushing and mixing of coal, an adhesion agent,
and an organic waste component to produce a uniform feedstock and subsequent heating of the feedstock, wherein as the adhesion agent are used the high boiling point products of plastic waste pyrolysis, which are added to the feedstock in an amount of 15% to 20% of the total feedstock volume and wherein the feedstock is heated in the temperature range 250°C to 1100°C.

Advantageously, the feedstock heating process is carried out in the temperature range of 250°C to 1100°C. At a temperature lower than 250°C, structural changes resulting in the formation of a solid-coke body do not occur in the feedstock. At a temperature higher than 1100°C, the coke formed lacks its quality characteristics this resulting in worse strength characteristics of the product.

As the high boiling point products of plastic waste pyrolysis, medium-molecular-weight tar-like products are used, which are produced in the temperature range of 250°C to 380°C under atmospheric pressure in the presence of catalysts. The heat treatment of a plastic waste mixture in the presence of catalysts at a temperature of 250°C to 380°C results in pyrolytic reactions in the plastic waste and chemical interaction between the products of pyrolysis to form medium-molecular-weight tar-like products of aromatic structure. In addition, said products of pyrolysis, which are a chemical analogue of the primary tar of pyrolysis of coal, may also act as the so called liquid nonvolatile components of the plastic-coal mass and ensure the formation of a solid-coke body. The medium-molecular-weight tar-like products act in the presence of catalysts so that, at the initial stage of pyrolysis of coal, said products act as a hydrogen-donating solvent, that is to say, they liquefy the coal. The coal liquefaction products comprise a mixture of over five hundred individual chemicals of polycyclic and aromatic structure. At the stage of the plastic state of the coal at the temperature of 350°C to 500°C, the medium-molecular-weight tar-like products act as plasticizing agents, because, owing to aromatic structure of their components, they are heat-resistant compounds and widen the temperature range of the plastic state of coal. Derivatives of anthracene, phenanthrene, coronene, pyrene, fluorene, naphthalene contained in the medium-molecular-weight tar-like products increase content of nonvolatile components in the coal plastic mass and, in this way, increase the characteristics of the plastic-coal mass. Said products also serve as hydrogen
donators to the components of the plastic-coal mass thus preventing untimely start of condensation reactions of the products of coal pyrolysis. This also contributes to widening of the temperature range of the plastic state of coal and improving its coking properties. As a result, the action of the medium-molecular-weight tar-like products causes formation of the solid semi-coke from noncaking coals. As the heating temperature rises up to 1100°C during the coking process, the coke is formed from such semi-coke, which coke has high quality and may be used in the blast-furnace process. It may be said that, at different stages of the process, the medium-molecular-weight tar-like products act as liquefiers, plasticizers, hydrogen donators, as well as caking additions to the coal. Therefore, addition of the medium-molecular-weight tar-like products to the feedstock composition enables production of the solid-coke body of desired high quality using noncaking coals of low cost; in this way cost efficiency of said method is achieved. Moreover, use of plastic waste to form the medium-molecular-weight tar-like products enables recycling of plastic waste on a large scale and, thus, helps to protect the environment.

Addition of high boiling point products of plastic waste pyrolysis, and namely, medium-molecular-weight tar-like products, to the feedstock in an amount of 15% to 20% of the total volume of the feedstock makes it possible to increase the coke yield from such feedstock up to 50% to 55% of the total volume depending on the properties and content of the used noncaking coals, as well as to ensure thickness Y of the coke plastic layer at the level of 16-18 mm. Said percentage range of the content of the medium-molecular-weight tar-like products is conditioned by the fact that such volume of the adhesion agent imparts sufficient plastic properties to the feedstock and this, in its turn, ensures solidity of the coke body. Addition of the medium-molecular-weight tar-like products to the feedstock in an amount of less than 15% will not ensure sufficient plastic properties of the feedstock, this resulting in cracking and disintegration of the coke body formed during the process. Addition of the medium-molecular-weight tar-like products to the feedstock in an amount of more than 20% of the feedstock volume is inexpedient because the content of the medium-molecular-weight tar-like products of 20% of the feedstock volume is sufficient to impart desired plastic properties to the feedstock.
Use of catalysts ensures a significant increase in both the effectiveness and the rate of formation of the medium-molecular-weight tar-like products during the chemical reaction. At that, another essential condition is presence of air oxygen, which is necessary for tarring of the products of the plastic waste pyrolysis into the medium-molecular-weight tar-like products. Preferably, transition metal oxides are used as the catalysts.

Said temperature range of 250°C to 380°C for obtaining the medium-molecular-weight tar-like products is conditioned by the fact that chemical polycondensation reactions of the medium-molecular-weight tar-like products occur exactly in this temperature range. At a heating temperature of less than 250°C, the polycondensation reactions of medium-molecular-weight tar-like products do not occur and, therefore, one of the basic conditions for performing this method of producing coke from noncaking coals is not ensured, namely formation of the medium-molecular-weight tar-like products used as the adhesion agent. At a temperature of more than 380°C, other chemical reactions occur, which do not relate to embodiment of this method since they do not result in formation of medium-molecular-weight tar-like products.

Restriction of the pressure by atmospheric pressure in conditioned by the fact that atmospheric pressure is quite sufficient to raise the reaction temperature to the desired level without substantial stripping of the products of pyrolysis of the primary components. Such conditions render the reactions easy to conduct, this also contributing to the cost efficiency of the method according to invention.

Preferably, worn-out automobile tires waste is used as the organic waste. Addition of worn-out automobile tires waste contributes to intensification of chemical reactions occurred owing to polyconjugated unsaturated bonds in the products of pyrolysis of worn-out automobile tires. In addition, the fine carbon contained in worn-out automobile tires becomes included in the coke and contributes to an increase in the coke yield. Moreover, use of worn-out automobile tires to practice the method according to the invention enables large-scale recycling of the tires and thus contributes to improving the ecological situation in big cities.
The objective of this invention is also achieved by the device for producing coke from noncaking coals, the device comprising a fire-resistant coking chamber; heating ducts; burners; means for charging the material to be coked; means for discharging the coke; as well as a heating tank provided with a charging hole for charging plastic waste, organic waste, and catalysts; and a flight conveyor to remove undissolved residues from said heating tank.

The fire-resistant coking chamber is made in the form of a vertical tower, in the walls of which there are arranged peripheral descending air ducts and internal heating ducts ascending to a flue gas exhauster; in the bottom of the tower, the air ducts and heating ducts are connected to fire-chambers with burners; a gas collector being connected to the top of the chamber and the bottom of the tower being made tapered and provided with an inside gate, through which the chamber is connected to the quenching receiver. Preferably, the inside gate is provided with a pressure sensor so that said inside gate may only be opened by producing a signal to the opening mechanism of the inside gate when a sufficient quantity of coke is accumulated on the surface of the inside gate. Provision of the device according to the invention with the inside gate of such design makes it possible to ensure tightness of the fire-resistant chamber this, in turn, ensuring environmental safety of the device according to the invention and to improve the operators' working conditions.

Tapering in the bottom of the fire-resistant tower causes coke retention in the baking zone for the desired period, this ensuring high quality of the obtained coke. The baked coke passes by gravity through the tapering due to shrinkage and development of shrinkage cracks.

Advantageously, the outer wall of the fire-resistant coking chamber is made of fire-clay brick. Fire clay is a fired fire-resistant clay, containing the mullite 3Al2O3-2SiO2 (40% Al2O3, the remainder SiO2); its fire resistance being 1670°C to 1750°C. The fire clay is produced by firing fire-resistant or refractory clays at the temperature of 1000°C to 1400°C.
The air ducts are provided to ensure air supply to the burners. The air is fed to
the burners from top to bottom this enabling heat recovery, i.e. reduction of the loss of heat
used to heat the outer walls of the internal heating ducts. In addition, due to gradual
raising of the feedstock treatment temperature and the movement of the steam and gas
products of pyrolysis from the hot zone to the cold zone, the chemical composition of
said steam and gas products remains stable, this enabling further utilization of said steam
and gas products, for example, in the production of motor fuel. Both air ducts and heating
ducts are connected to the fire-chambers with the burners, which are intended to burn the
heating gas. As the heating gas, the return coke oven gas may be used.

The heating ducts are connected to the flue gas exhauster, which is used to remove
the flue gas, which is a product of the heating gas burning, from the heating ducts.
Preferably, the heating ducts are made of a long length (up to 25 meters) to ensure
effective utilization of the heat produced by burning the heating gas. Thus, the tall height
of the fire-resistant chamber made in the form of a vertical tower ensures the desired
hydrostatic pressure at the bottom of a coke cake - up to 0.2 kgf/cm² to form a solid-coke
body.

Furthermore, the fire-resistant chamber is provided, in its top, with a gas collector,
which serves to remove and catch the steam and gas products of coking from the interior
of the fire-resistant chamber, this also contributing to the environment safety of the
device according to the invention.

As the means for charging the material to be coked, a metering hopper and a
screw-type feeder-gate are provided. Provision of such screw-type feeder-gate makes it
possible to ensure continuous supply of the feedstock into the fire-resistant chamber this,
in turn, being one of the conditions for ensuring continuous operation of the device for
producing coke from noncaking coals according to the invention and resulting in a
significant increase in the output of said device, as well as in a reduction of its operating
costs. In addition, the screw-type feeder-gate ensures a smokeless and flameless charging
process, this significantly reducing the harmful effect of device operation on the
environment.
As the means for discharging the coke, an outside gate is employed. Such design of the device for producing coke from noncaking coals ensures its tightness, as well as makes it possible to practice a smokeless and flameless coke discharging process, this, in turn, ensuring environmental safety of the device according to the invention and significantly improving the operators' working conditions.

Both the inside gate and the outside gate may be of any suitable design, for example, they may be made in the form of a slide gate, a sector gate or leaf shutter.

Description of drawings.

Fig. 1 shows a schematic diagram of the charging part of the device for producing coke from noncaking coals according to the invention,

Fig. 2 shows a schematic diagram of the processing part of the device for producing coke from noncaking coals according to the invention.

In Fig. 1, there is shown the charging part of the device for producing coke from noncaking coals, which comprises the heating tank 1 for charging plastic waste, organic waste and catalysts, and which is provided with the charging hole 2. Also, the charging part of the device comprises a flight conveyor 3 for removing undissolved residues from said heating tank 1.

In Fig. 2, there is shown the processing part of the device for producing coke from noncaking coals, which comprises means for charging material to be coked, the means comprising a metering hopper 4 and a screw-type feeder-gate 5. Furthermore, the processing part of the device comprises a fire-resistant chamber 6 made in the form of a vertical tower. In the walls of said fire-resistant chamber there are provided air ducts 7, as well as heating ducts 8. The heating ducts 8 are connected, in the top part, to a flue gas exhauster 9. In the bottom of the fire-resistant chamber 6, the air ducts 7 and the heating ducts 8 are connected to fire-chambers with burners 10. In addition, the fire-resistant chamber 6 is provided with a gas collector 11 connected to the top of said chamber 6. The fire-resistant chamber 6 also comprises the bottom part 12, which is tapered and connected, through an inside gate 14, to a quenching receiver 13 provided in the bottom
part of said fire-resistant chamber 6. Also, the fire-resistant chamber 6 comprises an outside gate 15 to discharge coke.

An exemplary embodiment of the method for producing coke from noncaking coals according to the invention is described below.

Plastic waste, catalysts and worn-out automobile tires are charged into the heating tank 1 through the charging hole 2. In the heating tank 1, plastic waste is melted, the worn-out automobile tires are dissolved and, thus, pyrolysis of said materials and reactions to form medium-molecular-weight tar-like products are performed. Further, the undissolved residue is removed from the heating tank 1 with the flight conveyor 3 and then melted. The medium-molecular-weight tar-like products, being in a liquid state, are pumped by means of a pump to the metering hopper 4, in which also the coal components are fed from the coal storage. By means of the screw-type feeder-gate, the feedstock is fed continuously, with the medium-molecular-weight tar-like products added, to the fire-resistant chamber 6 made in the form of a vertical tower. The feedstock is heated by the walls of the fire-resistant chamber 6 that comprises air ducts 7 and heating ducts 8. In the bottom of the tower, the air ducts 7 and the heating ducts 8 are connected to the fire-chambers with the burners 10, which serve for burning the heating gas. Air is supplied to the burners 10, from top to bottom, through the air ducts 7. Flue gas is removed from the heating ducts 8 through the flue gas exhauster 9. Steam and gas products of pyrolysis move from bottom to top. Said steam and gas products are fed to the gas collector 11 connected to the top of the fire-resistant chamber 6. While being heated the feedstock moves gradually down through the fire-resistant chamber 6, at that the temperature in the fire-resistant chamber 6 gradually rises in the direction towards its bottom. The coke being formed during this movement is baked in the baking area located in the bottom of the fire-resistant chamber 6 where the temperature reaches 1100°C. During baking the coke shrinks and cracks, the coke volume being 50-55% that of the feedstock. In the result of these processes, the formed coke moves through the tapered bottom 12 of the fire-resistant chamber onto the cover of the inside gate 14, which is provided with a pressure sensor, so that, when a sufficient quantity of coke is accumulated on the cover of the inside gate 14, the inside gate 14 opens in response to the signal sent to the opening
mechanism of the inside gate 14. At that, the coke moves to the quenching receiver 13 where coke is quenched. After quenching, the coke is discharged through the outside gate 15 and then transported to the finished-product storage area. Steam and gas products collected in the gas collector 11 are directed for cleaning with subsequent extraction from them of marketable products, such as gas spirit, raw benzene, tar pitch, ammonium sulfate, sulfur, as well as other products. The return coke oven gas is fed to heat the fire-resistant chamber 6.

The present invention provides a method and a device for producing coke from noncaking coals, which, owing to simplicity and effectiveness of the process and design of the device, ensure economic, safe and environment-friendly production of coke from noncaking coals, and at the same time ensure high quality of the obtained product.
Claims

1. A method for producing coke from noncaking coals, the method comprising metering, crushing and mixing of coal, an adhesion agent, and an organic waste component to produce a uniform feedstock and subsequent heating of the feedstock, characterized in that, as the adhesion agent, the high boiling point products of plastic waste pyrolysis are used, which are added to the feedstock in an amount of 15% to 20% of the total feedstock volume and wherein the feedstock is heated in the temperature range 250°C to 1100°C.

2. The method as claimed in claim 1, characterized in that, as the high boiling point products of plastic waste pyrolysis, the medium-molecular-weight tar-like products are used, which are produced in the temperature range of 250°C to 380°C under atmospheric pressure in the presence of catalysts.

3. The method as claimed in claim 1, characterized in that, as the organic waste component, worn-out automobile tire waste is used.

4. A device for producing coke from noncaking coals, the device comprising a fire-resistant coking chamber; heating ducts; burners; means for charging the material to be coked; a coke discharging means, characterized in that the device comprises a heating tank provided with a charging hole for charging plastic waste, organic waste, and catalysts; and with a flight conveyor for removing undissolved residues from said tank; the fire-resistant coking chamber being made in the form of a vertical tower, in the walls of which there are arranged peripheral descending air ducts and internal, ascending to a flue gas exhaueter, heating ducts; wherein in the bottom of the tower, the air ducts and heating ducts are connected to fire-chambers with burners, a gas collector being connected to the top of the chamber and the bottom of the tower being made tapered and provided with an inside gate, through which the chamber is connected to a quenching receiver.

5. The device as claimed in claim 4, characterized in that the means for charging the material to be coked comprises a metering hopper and a screw-type feeder-gate.
6. The device as claimed in claim 4, characterized in that the inside gate is provided with a pressure sensor.

7. The device as claimed in claim 4, characterized in that the coke discharging means comprises an outside gate.
Fig. 1
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

- **ClOB 53/00** (2006.01)
- **ClOB 47/00** (2006.01)
- **C08J 11/00** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC.

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

- **ClOB 47/00**, 49/00, 51/00, 53/00-53/08, 57/00-57/04, C08J 11/00-1 1/04, CIOG 47/00-47/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Exp@ce net, PAJ, USPTO DB

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
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<td>SU 920066 A (BRENSHTOFFINSTITUT FRAYBERG) 15.04.1982</td>
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<td>A</td>
<td>RU 2178440 C1 (SALTANOV ANDREY VLADIMIROVICH et al.) 20.01.2002</td>
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<td>US 5356530 A (ALBERT CALDERON) 18.10.1994, fig. 3, desc.</td>
<td>4-7</td>
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Further documents are listed in the continuation of Box C. See patent family annex

- **A** document defining the general state of the art which is not considered to be of particular relevance
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