METHODS AND SYSTEMS FOR TREATING CARBONACEOUS MATERIALS

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Description:
A method for treating a carbonaceous material including heating a carbonaceous material to move at least a portion of tar through the carbonaceous material toward a surface of the carbonaceous material to form a tar coating on the surface. The method also includes cooling the carbonaceous material and the tar coating on the surface to form a tar-coated carbonaceous material, wherein at least the portion of tar that forms the tar coating on the surface remains in contact with the carbonaceous material while the carbonaceous material is heated to form the tar coating and while the carbonaceous material and the tar coating are cooled to form the tar-coated carbonaceous material.
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CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of U.S. patent application Ser. No. 13/764,769, entitled "METHODS AND SYSTEMS FOR TREATING CARBONACEOUS MATERIALS," filed Feb. 11, 2013, which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The subject matter disclosed herein relates to methods for treating carbonaceous materials, and more particularly to methods for treating carbonaceous materials which improve the removal of ash from carbonaceous materials, and systems related thereto.

[0003] Different technologies are used to generate energy from organic or fossil-based carbonaceous materials such as coal. Different types of coal, such as lignite, or brown coal, subbituminous coal, bituminous coal, or black coal, anthracite and/or graphite, are utilized in energy producing systems. These different types of coal are categorized, or ranked, according to their particular physical properties, e.g., "low-rank coal" and "high-rank coal".

[0004] Varying amounts of ash are present in naturally occurring carbonaceous materials such as coal. Ash is the non-combustible residue of mineral matter present in the carbonaceous material. Some coal materials have an ash content of greater than 20%, or even greater than 50%. The greater the ash content of the raw coal material, the lower amount of coal that will be available for energy production. High ash contents are also generally undesirable because of the potential for contamination of the equipment used in the energy production due to impurities present in the ash.

[0005] Carbonaceous materials such as coal are therefore subjected to an ash removal treatment on. Ash is separated from coal based upon differences between the inherent surface properties of the ash, which is hydrophilic, i.e., attracts water, and the coal, which is hydrophobic, i.e., repels water. Coal washing and/or flotation columns, for example, are used to separate the ash from the coal by taking advantage of the hydrophilic nature of the surface of the ash and the hydrophobic nature of the surface of the coal. Therefore, the amount of ash which is removed from coal using an ash removal treatment is limited by the extent of these inherent surface properties.

[0006] Consequently, the ash content of coal materials which have a significant amount of ash cannot be sufficiently lowered using an ash removal treatment without the use of one or more additives. Various additives are employed in order to enhance the separation of the hydrophobic coal from the hydrophilic ash in order to provide a coal material with suitably low ash content for use in energy production. Such additives represent a significant cost in materials and/or process efficiency.

[0007] It is therefore desirable to provide a method for treating carbonaceous materials in order to improve the removal of ash from carbonaceous materials, and systems related thereto, which solve one or more of the aforementioned problems.

BRIEF DESCRIPTION OF THE INVENTION

[0008] According to one aspect of the invention, a method for treating a carbonaceous material comprises heating a carbonaceous material to form a mixture of the carbonaceous material and a tar, cooling the mixture of the carbonaceous material and the tar, and coating a surface of the carbonaceous material with the tar to form a tar-coated carbonaceous material.

[0009] According to another aspect of the invention, a system for treating a carbonaceous material comprises a heating region, the heating region being operative to heat a carbonaceous material to form a mixture of the carbonaceous material and a tar; a cooling region, the cooling region being operative to cool the mixture of the carbonaceous material and the tar and to coat a surface of the carbonaceous material with the tar to form a tar-coated carbonaceous material.

[0010] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0012] FIG. 1 is a block flow diagram of a method for treating a carbonaceous material; and

[0013] FIG. 2 is a schematic diagram of a system for treating a carbonaceous material.

[0014] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Embodiments described herein generally relate to methods for treating a carbonaceous material and systems related thereto. A method for treating a carbonaceous material is provided to modify the surface of the carbonaceous material in order to improve the separation of ash from the carbonaceous material.

[0016] Referring to FIG. 1, the method for treating a carbonaceous material comprises heating a carbonaceous material. Upon heating, a tar is released from the carbonaceous material to form a mixture of the carbonaceous material and the tar. The method further comprises cooling the mixture of the carbonaceous material and the tar. Upon cooling, at least a portion of the tar released from the carbonaceous material coats at least a portion of a surface of the carbonaceous material to form a tar-coated carbonaceous material.

[0017] The carbonaceous material is any carbon-rich and/or hydrocarbon-based material. In one embodiment, the carbonaceous material comprises coal. In another embodiment, the carbonaceous material comprises low-rank coal, high-rank coal, or a combination comprising at least one of the foregoing. In yet another embodiment, the carbonaceous material comprises lignite, or brown coal, subbituminous coal, bituminous coal, or black coal, anthracite, graphite or a combination comprising at least one of the foregoing.

[0018] In one embodiment, the carbonaceous material comprises crushed coal. The coal is crushed using any appropriate crushing method and/or equipment, such as for
example, a coal crusher, a coal shredder and/or a coal grinder. The coal is ground, crushed and/or shredded into smaller particles prior to heating.  

[0019] The carbonaceous material comprises varying amounts of ash, including for example, high ash, e.g., greater than about 50% total ash content, and low ash, e.g., less than about 30% total ash content. In one embodiment, the carbonaceous material has a total ash content of about 10% to about 80% prior to heating. In another embodiment the carbonaceous material has a total ash content of about 10% to about 50% prior to heating. In yet another embodiment, the carbonaceous material has a total ash content of about 30% to about 50% prior to heating.

[0020] The carbonaceous material is heated as a solid or a suitable solvent is mixed with the carbonaceous material to form a solution or a wet slurry. In one embodiment, the carbonaceous material is heated in a solid phase and/or in a dry state. In another embodiment, the carbonaceous material is mixed with water or another suitable solvent to form a solution or a wet slurry prior to heating.

[0021] The carbonaceous material is heated at a pressure which is sufficient to release a tar, or oil, from within the carbonaceous material. The tar, or oil, is an organic material which is derived from the carbonaceous material. In one embodiment, the heating of the carbonaceous material is carried out at a pressure of less than about 5 atmospheres. In another embodiment, the heating of the carbonaceous material is carried out at a pressure of from about 1 to about 5 atmospheres.

[0022] The carbonaceous material is heated to a temperature effective to release tar, or oil, from the carbonaceous material. In one embodiment, the carbonaceous material is heated to a temperature of from about 300°C to about 500°C. In another embodiment, the carbonaceous material is heated to a temperature of from about 350°C to about 450°C. In yet another embodiment, the carbonaceous material is heated to a temperature of from about 375°C to about 425°C.

[0023] At temperatures lower than about 300°C, an insufficient amount of tar is released from the carbonaceous material and/or the tar released will be less complex in composition, and therefore less hydrophobic than tar released at a temperature of greater than about 300°C and less than about 500°C. At temperatures higher than about 500°C, the tar released from the carbonaceous material will not adequately coat the carbonaceous material or at least a portion of the carbonaceous material, e.g., reaction of the tar is promoted above these temperatures.

[0024] The heating of the carbonaceous material is accomplished using any suitable heating method and/or heat source. Examples of suitable heating methods and/or heat sources include pyrolysis, flash pyrolysis, partial oxidation, microwave energy, other conventional heating methods and/or heat sources or a combination comprising at least one of the foregoing.

[0025] In one embodiment, the heating of the carbonaceous material is accomplished using microwave energy. The microwave energy used to heat the carbonaceous material is supplied by a microwave energy generation device, such as a magnetron in a microwave oven. Wave energy generated by the magnetron is transferred to the carbonaceous material using, for example, a wave guide or a wave tube.

[0026] The amount of microwave energy and the frequency of the microwave energy are selected to release the tar from the carbonaceous material at a desired temperature. In one embodiment, the microwave energy may be generated in a range of from about 100 kilo Watt per pound (kW/lb) to about 1,000 kilo Watt per pound (kW of power per lb of carbonaceous material). In another embodiment, the frequency of the microwave energy generated is about 800 MHz or about 2.45 GHz. The heating of the carbonaceous material is carried out in the presence or absence of a resonator.

[0027] Microwave energy is transferred through the carbonaceous material electro-magnetically, not as a convective force or a radiative force. Therefore, the rate of heating is not limited by surface transfer, and the uniformity of heat distribution is greatly improved. Heating times can be reduced to less than 1% of that required using other heating techniques. In one embodiment, the heating of the carbonaceous material with microwaves is precisely controlled with respect to the amount of heat applied, such that a precise temperature may be maintained at all times. In other words, substantially all portions of the carbonaceous material are exposed to the same temperature. For example, particles of the carbonaceous material form aggregates, or “lumps”. The center of each “lump” of carbonaceous material is at the same temperature as the surface of that lump. Thus, the tar released from the carbonaceous material, under the effect of the heat generated by microwaves, is not subjected to any temperatures higher than that which is needed to release the tar. In addition, since the uniformity of heat distribution is improved due to the generation of the microwave energy, the tar is released from the carbonaceous material more uniformly.

[0028] The carbonaceous material is heated in the presence or absence of additives, such as additional tar, which increase the hydrophobicity of the carbonaceous material or otherwise enhance the separation of carbonaceous material from ash. In one embodiment, the mixture of carbonaceous material and the tar is devoid of tar from any source external to the carbonaceous material, i.e., not already present within the carbonaceous material prior to heating or which is not derived from the particular carbonaceous material used in the method upon heating. In this embodiment, the oil or mixture of the carbonaceous material and the tar that was released from the carbonaceous material upon heating.

[0029] In another embodiment, additional tar from an external source other than the carbonaceous material is added to the carbonaceous material prior to heating and/or to the mixture of the carbonaceous material and the tar formed during and/or after heating the carbonaceous material. In another embodiment, the additional tar is derived from a carbonaceous material and/or is a biomass material.

[0030] The mixture of the carbonaceous material and the tar is cooled by removing, discontinuing or lowering the heat temperature from the heat source described above and/or by transporting the mixture of carbonaceous material and the tar to a region which is not subjected to such heat from said heat source. In one embodiment, the mixture of the carbonaceous material and the tar is cooled to a temperature of between about 0°C and about 300°C. In another embodiment, the mixture of the carbonaceous material and the tar is cooled to a temperature of between about 0°C and about 200°C. In yet another embodiment, the mixture of the carbonaceous material and the tar is cooled to a temperature of between about 0°C and about 100°C. In one embodiment, the cooling of the mixture of the carbonaceous material and the tar directly follows the heating of the carbonaceous material.
Upon cooling of the mixture of the carbonaceous material and the tar, at least a portion of a surface of the carbonaceous material is coated with at least a portion of the tar. The tar released from the carbonaceous material is hydrophobic in nature. The resulting tar-coated carbonaceous material is thus a surface-modified carbonaceous material. The coated tar increases the number of hydrophobic functional groups on the surface of the carbonaceous material, thereby increasing the overall hydrophobicity of the surface of the carbonaceous material. The increased hydrophobicity of the surface of the carbonaceous material improves the separation of the hydrophobic tar-coated carbonaceous material from the hydrophilic ash in a subsequent ash removal process.

In one embodiment, a surface of the tar-coated carbonaceous material is about 10% to about 80% more hydrophobic than the surface of the carbonaceous material prior to being subjected to said heating, cooling and coating. In another embodiment, a surface of the tar-coated carbonaceous material is about 20% to about 80% more hydrophobic than the surface of the carbonaceous material prior to being subjected to said heating, cooling and coating. In yet another embodiment, a surface of the tar-coated carbonaceous material is about 30% to about 80% more hydrophobic than the surface of the carbonaceous material prior to being subjected to said heating, cooling and coating.

In another embodiment, the carbonaceous material is partially coated with the tar released from the carbonaceous material. In yet another embodiment, the carbonaceous material is uniformly coated with the tar released from the carbonaceous material. In still another embodiment, the carbonaceous material is heated using microwave energy and is uniformly coated with the tar released from the carbonaceous material. In still yet another embodiment, the carbonaceous material is crushed coal which is heated using microwave energy and uniformly coated with the tar released from the carbonaceous material.

The tar-coated carbonaceous material is subsequently subjected to at least one ash removal process with or without the use of additives to enhance the separation of the tar-coated carbonaceous material from the ash. In one embodiment, the tar-coated carbonaceous material is devoid of any additive to enhance the separation of the carbonaceous material from the ash. In another embodiment, the tar-coated carbonaceous material further comprises at least one additive to enhance the separation of the tar-coated carbonaceous material from the ash.

Referring back to FIG. 1, in one embodiment, the method further comprises removing ash from at least a portion of the tar-coated carbonaceous material. The tar-coated carbonaceous material is subjected to any ash removal process suitable to separate the tar-coated carbonaceous material from the ash mixed therewith on the basis of the differences between hydrophobic and hydrophilic surface properties. In one embodiment, removing ash from the tar-coated carbonaceous material is accomplished by a hydro-treatment. The hydro-treatment involves washing the tar-coated carbonaceous material with water or another suitable solvent, for example in a separation or flotation column. As the tar-coated carbonaceous material is washed, e.g., with water, the hydrophobic tar-coated carbonaceous material is separated from the hydrophilic ash mixed therewith.

The method described herein allows for greater removal of ash from a carbonaceous material when compared to a carbonaceous material which is not subjected to said method. In one embodiment, the tar-coated carbonaceous material is subjected to a hydro-treatment to remove ash in which a total ash content of the tar-coated carbonaceous material is reduced to about 0% to about 50%. In another embodiment, the tar-coated carbonaceous material is subjected to a hydro-treatment to remove ash in which a total ash content of the tar-coated carbonaceous material is reduced to about 30% to about 50%. In yet another embodiment, the tar-coated carbonaceous material is subjected to a hydro-treatment to remove ash in which a total ash content of the tar-coated carbonaceous material is reduced to about 0% to about 30%. In still another embodiment, the tar-coated carbonaceous material is subjected to a hydro-treatment to remove ash in which a total ash content of the tar-coated carbonaceous material is reduced to about 5% to about 20%.

In still yet another embodiment, the tar-coated carbonaceous material is subjected to a hydro-treatment to remove ash in which a total ash content of the tar-coated carbonaceous material is reduced to about 15% or less.

Referring to FIG. 2, a system for treating a carbonaceous material is provided. A system 10 for treating a carbonaceous material comprises a heating region 20, the heating region 20 being operative to heat a carbonaceous material (not shown) to form a mixture of the carbonaceous material and a tar; and a cooling region 30, the cooling region 30 being operative to cool the mixture of the carbonaceous material and the tar and to coat at least a portion of a surface of the carbonaceous material with at least a portion of the tar to form tar-coated carbonaceous material. The cooling region 30 is disposed downstream of the heating region 20.

In one embodiment, the system 10 further comprises a carbonaceous material processing column 40 which contains the carbonaceous material and a transport system 50 which transports the carbonaceous material to the heating region 20 and from the heating region 20 to the cooling region 30. In another embodiment, the transport system 50 is a conveyor belt.

In one embodiment, the system 10 further comprises a heating unit 60, which supplies heat to the heating region 20. In one embodiment, the heating unit 60 controls the heat supplied to the heating region 20. In another embodiment, the system 10 further comprises an optional collecting region 70. The collecting region 70 collects the tar-coated carbonaceous material subsequent to the heating, cooling and coating of the carbonaceous material in the heating region 20 and cooling region 30, respectively. The collecting region 70 is disposed downstream of the heating region 20 and the cooling region 30.

In one embodiment, the system 10 further comprises a feedback loop 80. The feedback loop 80 senses the temperature in the heating region 20 and supplies this information to the heating unit 60. The heating unit 60 uses information from the feedback loop 80 to regulate the temperature in the heating region 20.

In one embodiment, the system 10 further comprises an ash removal region 90 in which ash is removed or separated from the tar-coated carbonaceous material. The ash removal region 90 is disposed downstream of the heating region 20 and the cooling region 30, as well as the optional collecting region 70.

In one embodiment, the system 10 further comprises additional equipment including, but not limited to, feed hoppers, crushers, grinders, mixers, conical separators, con-
control units, cooling units, collection units, transport devices, shredders, heaters, screw feeders and/or other related equipment.

[0043] The methods and systems described herein pre-treat the carbonaceous material using tar released or derived from the carbonaceous material itself to partially or uniformly coat the carbonaceous material. The resulting surface-modified, tar-coated carbonaceous material has an increased overall hydrophobicity, which improves the separation of ash from carbonaceous materials which have undesirably high ash contents in an ash removal process. The methods and systems described herein thereby make such ash-containing carbonaceous materials suitable for subsequent use in a process which uses low ash coal, e.g., to generate energy. In this manner, the methods and systems provided herein allow for the use of relatively high-ash containing carbonaceous materials which would otherwise be rendered unsuitable due to their high ash content. The methods and systems described herein are also used to treat carbonaceous materials with or without the use of additional tar from an external source other than the carbonaceous material and/or with or without the use of other additives.

[0044] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

1. A method for treating a carbonaceous material comprising:

heating a carbonaceous material to move at least a portion of tar through the carbonaceous material toward a surface of the carbonaceous material to form a tar coating on the surface; and

cooling the carbonaceous material and the tar coating on the surface to form a tar-coated carbonaceous material, wherein at least the portion of tar that forms the tar coating on the surface remains in contact with the carbonaceous material while the carbonaceous material is heated to form the tar coating and while the carbonaceous material and the tar coating are cooled to form the tar-coated carbonaceous material.

2. The method of claim 1, wherein the carbonaceous material comprises coal.

3. The method of claim 1, comprising heating the carbonaceous material to a temperature of from about 300 degrees Celsius to about 500 degrees Celsius using a heat source.

4. The method of claim 1, comprising heating the carbonaceous material by applying electromagnetic energy from an electromagnetic energy source and cooling the carbonaceous material and the tar coating on the surface by discontinuing the application of heat from the electromagnetic energy source.

5. The method of claim 1, comprising adding additional tar to the carbonaceous material from an external source other than the carbonaceous material.

6. The method of claim 5, wherein the additional tar is added to the carbonaceous material during the heating of the carbonaceous material.

7. The method of claim 1, wherein an outer surface of the tar-coated carbonaceous material is about 10 percent to about 80 percent more hydrophobic than the surface of the carbonaceous material prior to the heating step of the method.

8. The method of claim 1, wherein the carbonaceous material has a total ash content of about 30 percent to about 50 percent.

9. The method of claim 1, comprising applying a liquid to the tar-coated carbonaceous material to cause ash to separate from the tar-coated carbonaceous material.

10. The method of claim 9, wherein a total ash content of the tar-coated carbonaceous material is less than about 30 percent after application of the liquid to the tar-coated carbonaceous material.

11. A method for treating a carbonaceous material comprising:

heating a carbonaceous material to move at least a portion of tar through the carbonaceous material toward a surface of the carbonaceous material to form a tar coating on the surface; and

cooling the carbonaceous material and the tar coating on the surface to form a tar-coated carbonaceous material, wherein an outer surface of the tar-coated carbonaceous material after the cooling is about 10 percent to about 80 percent more hydrophobic than the surface of the carbonaceous material prior to the heating.

12. The method of claim 11, wherein the tar-coated carbonaceous material is formed without separating the portion of the tar that forms the tar coating from the carbonaceous material during the heating and the cooling.

13. The method of claim 11, wherein the heating of the carbonaceous material comprises applying electromagnetic energy using an electromagnetic energy source.

14. The method of claim 11, comprising adding additional tar to the carbonaceous material from an external source other than the carbonaceous material during the heating of the carbonaceous material.

15. The method of claim 11, comprising applying a liquid to the tar-coated carbonaceous material to cause ash to separate from the tar-coated carbonaceous material, wherein a total ash content of the tar-coated carbonaceous material is less than about 30 percent after applying the liquid to the tar-coated carbonaceous material.

16. A method for treating a carbonaceous material comprising:

heating a carbonaceous material with an electromagnetic energy source within a heating region of a carbonaceous material treatment system to move at least a portion of tar through the carbonaceous material toward a surface of the carbonaceous material to form a tar coating on the surface; and

transporting the carbonaceous material from the heating region to a cooling region of the carbonaceous material treatment system, wherein the cooling region is separate from and downstream of the heating region and is not subjected to heat from the heat source of the heating region, thereby enabling the carbonaceous material and the tar coating on the surface to cool and to form a tar-coated carbonaceous material.
17. The method of claim 16, comprising:
transporting the tar-coated carbonaceous material from the
cooling region to an ash-removal region of the carbon-
aceous material treatment system, wherein the ash-re-
moval region is separate from and downstream of the
heating region and the cooling region; and
washing the tar-coated carbonaceous material with a liquid
in the ash-removal region to cause ash to separate from
the tar-coated carbonaceous material.

18. The method of claim 16, wherein an outer surface of the
tar-coated carbonaceous material is about 10 percent to about
80 percent more hydrophobic than the surface of the carbon-
aceous material prior to the heating step of the method.

19. The method of claim 16, wherein a total ash content of
the tar-coated carbonaceous material is less than about 30
percent after applying the liquid to the tar-coated carbon-
aceous material.

20. The method of claim 16, wherein at least the portion of
tar that forms the tar coating on the surface remains in contact
with the carbonaceous material while the carbonaceous mate-
rial is heated to form the tar coating and while the carbon-
aceous material and the tar coating are cooled to form the
tar-coated carbonaceous material.