

PLASMA PYROLYSIS SYSTEM AND METHOD FOR TYRES

FIELD OF THE INVENTION

The invention relates to a system and method of recycling waste tyres. Specifically, the invention relates to using high energy gas flow tyre pyrolysis to convert waste tyres into energy. More specifically, the invention relates to using Radio Frequency (RF) inductive plasma heating together with Low Frequency (LF) induction heating to recycle waste tyres into useable products and electricity.

BACKGROUND TO THE INVENTION

The following discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or part of the common general knowledge in any jurisdiction as at the priority date of the application.

Cities and industries around the world are searching for environmentally friendly solutions to their waste tyre management problems instead of the usual methods of burning waste tyres in a furnace or increasing scrap tyre land fill sites. One proposed solution is to use pyrolysis systems, which involves the thermochemical decomposition of organic materials at elevated temperatures in the absence of oxygen (or any halogen).

The majority of current plasma pyrolysis systems use plasma arc technology which uses two electrodes, usually made of consumable carbon, which has electricity passed through them to produce hot arc plasma between them. These electrodes require frequent replacement and the electrode design is limited in its configurations and parameters. Such a method also produces health and environmental hazards through the production of waste products.

SUMMARY OF THE INVENTION

Throughout this document, unless otherwise indicated to the contrary, the terms “comprising”, “consisting of”, and the like, are to be construed as non-exhaustive, or in other words, as meaning “including, but not limited to”.

It would be advantageous to provide a system and method of recycling waste tyres that reduces the aforementioned problems associated with the prior art systems and makes an improvement in the art. A first advantage of the system and method in accordance with this invention is that it converts waste tyres into useable products and electricity. A second advantage of the system and method in accordance with this invention is that it does not require landfill sites and converts the growing number of waste tyres into a useful product. A third advantage of the system and method in accordance with this invention is that pollution is reduced to virtually zero.

In accordance with a first aspect of the invention there is a method for converting waste tyres into syngas comprising the steps:

- comminuting rubber from waste tyres into a powder;
- introducing said powder into a powder injector;
- injecting said powder from the powder injector into an induction thermal processor; and
- obtaining syngas at an outlet of said induction thermal processor.

Preferably, the method also comprises the step of obtaining carbon black at an outlet of the induction thermal processor.

Preferably, a turbine and a generator is used to generate electricity using the syngas produced.

Preferably, the electricity generated is used to power a system to convert waste tyres into syngas.

Preferably, the powder is introduced into the powder injector via a carrier gas.

Preferably, the powder is introduced via the carrier gas into a plasma torch of the powder injector.

Preferably, the carrier gas is selected from the group comprising argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.

Preferably, the plasma torch uses gas that is selected from the group comprising argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.

Preferably, the method comprises a further step of setting the powder to have a particle size ranging from 100 microns to 25mm.

Preferably, the method comprises a further step of setting the powder feeder rate to the powder injector between 1kg per hour and 2 tonnes per hour.

Preferably, the method comprises a further step of setting the induction frequency of a LF induction coil in the induction thermal processor between 1 kHz and 500 kHz.

Preferably, the method comprises a further step of setting the temperature in the induction thermal processor between 900 degrees Centigrade and 1200 degrees Centigrade.

Preferably, a carbon black product is obtainable at an outlet of the induction thermal processor.

Preferably, the carbon black product comprises a composition of 95% carbon, 2% silicon and 3% zinc oxide by weight.

In accordance with a second aspect of the invention there is a system for converting waste tyres into syngas and carbon black comprising

- means for comminuting rubber from waste tyres into a powder;
- a feeding system for feeding said powder into a powder injector;
- a powder injector for injecting said powder into an induction thermal processor; and
- an induction thermal processor for producing syngas and carbon black.

Preferably, the system further comprises a source of carrier gas connected to the feeding system.

Preferably, the powder injector comprises a plasma torch and an RF induction coil.

Preferably, the powder is introduced into the plasma torch of the powder injector.

Preferably, the plasma torch comprises a metal tube in which a plasma stream is created.

Preferably, the metal tube is made of copper.

More preferably, the plasma torch comprises a quartz tube in which a plasma stream is created.

Even more preferably, the quartz tube is shielded by a metal shield. Even more preferably, the quartz tube is shielded by a water-cooled metal shield.

Preferably, the metal shield is made of a non-magnetic material.

Preferably, the induction thermal processor comprises a chamber and a LF

induction coil.

Preferably, the chamber comprises a metal tube.

Preferably, the metal tube is made of ferromagnetic material.

Preferably, the metal tube is made of steel, preferably of stainless steel, graphite or carbon steel.

Preferably, the metal tube is coated with a ferromagnetic material.

Preferably, the metal tube is ceramic coated.

Preferably, the metal tube is graphite coated.

Preferably, the chamber is rotatable.

Preferably, the LF induction coil is rotatable.

Preferably, the longitudinal axis of the chamber is at an angle to the longitudinal axis of the powder injector.

Preferably, the longitudinal axis of the LF induction coil is at an angle to the longitudinal axis of the powder injector.

Preferably, the angle is between 0 and 90 degrees.

Preferably, the source provides the carrier gas selected from the group comprising of argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.

Preferably, the plasma torch uses gas that is selected from the group comprising of argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.

Preferably, the induction frequency of the LF induction coil is between 1 kHz and 500 kHz.

Preferably, the feeding system has a feeder rate of between 1kg per hour and 2 tonnes per hour to the powder injector.

Preferably, the temperature in the induction thermal processor is between 900 degrees Centigrade and 1200 degrees Centigrade.

Preferably, the temperature in the powder injector is between 6000 degrees Centigrade and 11000 degrees Centigrade.

Preferably, the powder used in the feeding system has a particle size ranging from 100 microns to 25mm.

In accordance with a third aspect of the invention there is a plasma reactor for converting rubber to syngas and carbon black comprising:

- an enclosed chamber with an inlet and an outlet;

- a plasma jet formed by passing a plasma gas through an RF induction coil, said plasma jet positioned proximal to said inlet; and

- a LF induction coil positioned proximal to said inlet but distal to said plasma jet;

wherein syngas and carbon black are obtained from said chamber.

Preferably, a carrier gas is introduced into the chamber using the inlet.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, with reference to

the accompanying drawings, in which:

Figure 1 is a flow chart of a method of converting waste tyres into synthetic gas (syngas) in accordance with a first embodiment of the present invention.

Figure 2 is an illustrative diagram of the plasma reactor.

PREFERRED EMBODIMENTS OF THE INVENTION

Particular embodiments of the present invention will now be described with reference to the accompany drawings. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the scope of the present invention. Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs.

In accordance with a first embodiment of the invention there is a method of converting waste tyres into syngas. The method 110 is illustrated in flow chart form in Figure 1.

As shown in Figure 1, the method 110 commences when waste tyres are fed into the system 112. A crushing and separation system 114 removes the steel from the waste tyres and compacts it before sending the steel to the steel mill 116. The remaining rubber is comminuted into a powder 118 through processes which are well known in the industry. The powder typically has particle size ranging from 100 microns to 25mm. In one embodiment, the size of the rubber powder used is between 400 microns and 600 microns. This rubber powder (or pulverized tyre) is then fed into a feeder which uses a carrier gas and feeds the rubber powder into a RF plasma reactor and LF induction chamber 120. The chamber contains the pyrolysis process and the output is mostly gaseous which is syngas, comprising predominantly of carbon monoxide and hydrogen. Carbon dioxide and long-chain hydrocarbons may also be present. Some output from the RF plasma and LF induction chamber is solid, which are base carbon powder

and this is commonly known in the industry as carbon black. This carbon black is packaged for sale to industries 122, while the syngas is sent to a scrubber 124. The scrubber removes any sulphur oxides and nitrogen oxides and sends the syngas to the electrostatic precipitator 126, which removes any residual carbon powder. The syngas is then burned in a gas turbine 128, which powers an engine generator 130 to produce electricity 132, as well as exhaust gases. The exhaust gases are sent for selective catalytic reduction 134, which removes any nitrogen oxides from the exhaust gas before being vented through the exhaust stack.

Engine generator systems are well known to those in the industry and include refined processes and systems to collect and remove any residual nitrogen oxide that occurs from burning the gas in the engine. This is crucial since nitrogen oxide is the only hazardous element from burning the syngas. The burning in the engine also breaks down any long-chain hydrocarbons in the exhaust gas.

The exhaust gas that is vented through the exhaust stack will have minimal amounts of nitrogen oxides and this will have a maximum of 20 parts per million (PPM), which is so minute that it would be difficult to measure using conventional or standard measuring instruments. Tests conducted have shown that the nitrogen oxides and carbon monoxide produced is 11 mg/NM³ and 13 mg/NM³ representing a significant reduction in nitrogen oxides and carbon monoxide produced by the existing prior art systems.

Tests conducted on the carbon black obtained also indicate a very high composition of carbon comprising 95% carbon by weight. Silicon and zinc oxide comprise the remaining 2% and 3% composition by weight.

A more detailed look at the RF plasma reaction chamber is shown in Figure 2. A feeder system 210 is used to feed the rubber powder into a powder injector 220 using a carrier gas. The carrier gas used to carry the rubber powder in an oxygen free environment into chamber can be argon, nitrogen, neon, helium, carbon dioxide or a mixture of any of these inert gases. The feed rate of the carrier gas is between 0 and 200 standard cubic feet per minute (SCFM), as aside from

using carrier gas, the powder can also be fed mechanically to the chamber. The size of the rubber powder used is between 100 microns and 25mm, although typically, a size of 400 microns to 600 microns is used. The feeder has a variable rubber powder feeding rate of between 1kg per hour and 2 tonnes per hour. One of the tested feeding rates which provided good returns was at 1 tonne per hour.

The RF plasma heater consists of a plasma torch and an RF coil. The plasma torch is made up of a quartz tube in combination with a water-cooled copper shield. This metal shield can also be any non-magnetic material. This acts as a pre-treatment before the induction thermal processor 230. The plasma frequency is between 66kHz and 150MHz, while the power used is between 1kW and 1MW. The gas feed rate for the plasma gas is between 0 and 10 cubic meters per hour, and the plasma gas used can be argon, nitrogen, neon, helium, carbon dioxide or a mixture of any of these inert gases. The pre-treatment can cause the rubber powder to partially decompose before fully decomposing in the induction thermal processor 230.

The induction thermal processor 230 is the reaction chamber where pyrolysis takes place and the chamber can be mounted such that it can be rotated, even while gas is flowing. The chamber can either be mounted stationary or rotated up to 10rpm. The chamber can be installed at an angle or be mounted completely vertical or horizontal, depending on the user specification. There are situations that require the chamber to be mounted at an angle of between 0 to 90°, i.e. completely horizontal to completely vertical. One embodiment of the chamber was mounted between 10 to 15 degrees to the powder injector. The induction thermal processor 230 has an LF induction heater and its frequency is between 1kHz and 500kHz while the power used is between 10kW and 5MW. In some instances, it would found the a frequency of between 1kHz and 40kHz was suitable. The LF induction heater can be mounted at various positions, including inside and outside the chamber. The LF induction heater can also be mounted at an angle or rotated, independent of the chamber. The induction thermal processor chamber can be made of stainless steel or carbon steel, and it can be

further coated with ceramic, graphite or any other magnetic material where induction can take place. The processing time in the induction thermal processor is dependent on the time required to decompose the rubber powder via pyrolysis, and the temperature in the chamber can range between 900°C and 1200°C. A convenient temperature which provided a good yield was 1000°C. The induction thermal processor produces exhaust gases, which is sent to the exhaust stack 240, consisting mainly of carbon monoxide and hydrogen, as well as a solid material known as carbon black.

RF induced electrode-less plasma system is a flexible pyrolysis technique and consists of passing gas through a plasma torch combined with RF power to form a hot plasma stream. This allows different gases to be used to control the end result and also eliminates the need to shut down the reactor to replace the electrodes (since there are no electrodes needed). An induction heater is attached to a conduit tube which is in turn attached to the RF plasma outlet and the conduit tube is used as the susceptor for LF Induction heater. The tube radiates and convectively heats the matter passing through the conduit tube. The pyrolysis takes place in oxygen starved high heat atmosphere that does not allow dioxins, furans, and other hazardous by-products to be produced. The RF induced plasma can operate at extremely high temperatures ranging from 6000 to 11000 degrees centigrade.

A separate LF induction heater is used in tandem with the RF plasma torch. The LF induction heater can be mounted after the RF plasma torch and can be mounted at an angle to the RF plasma torch to create a fluidized bath and allow the variation of rubber particle dwell time. This added dwell time breaks down any heavy oils, leaving behind long chain hydrocarbon gases that are used to increase the heating value of the syngas to produce energy from the waste tyres. Further, the LF induction heater can be rotated.

The conduit tube can be any metal that can be inductively heated, typically made of iron or any of its alloy (due to their ferromagnetic nature), and possible materials that was tested were steel or even graphite.

The different gas compositions from the tyre pyrolysis are affected by various factors including the reaction temperature, process dwell time, type of plasma gas and type of carrier gas. This variability of inputs provides the ability to produce a range in the parameters used during the recycling of the waste tyres.

It should be appreciated by the person skilled in the art that the above invention is not limited to the embodiment described. In particular, the following modifications and improvements may be made without departing from the scope of the present invention:

Waste material other than waste tyres may be processed using the method and system described above.

We Claim:

1. A method for converting waste tyres into syngas comprising the steps:
comminuting rubber from waste tyres into a powder;
introducing said powder into a powder injector;
injecting said powder from the powder injector into an induction thermal processor; and
obtaining syngas at an outlet of said induction thermal processor.
2. The method according to claim 1, further comprising the step of obtaining carbon black at an outlet of said induction thermal processor.
3. The method according to either of claims 1 or 2, further comprising the step of using a turbine and a generator to generate electricity using the syngas produced.
4. The method according to claim 3, wherein said electricity generated is used to power a system to convert waste tyres into syngas.
5. The method according to any of the preceding claims, wherein said powder is introduced into said powder injector via a carrier gas.
6. The method according to claim 5, wherein said powder is introduced via said carrier gas into a plasma torch of said powder injector.
7. The method according to claims 5 or 6, wherein the carrier gas is selected from the group comprising argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.
8. The method according to claim 6, wherein said plasma torch uses gas that is selected from the group comprising argon, nitrogen, neon, helium, carbon

dioxide, or a mixture of two or more thereof.

9. The method according to any of the preceding claims, comprising a further step of setting said powder to have a particle size ranging from 100 microns to 25mm.

10. The method according to any of the preceding claims, comprising a further step of setting the powder feeder rate to said powder injector between 1kg per hour and 2 tonnes per hour.

11. The method according to any of the preceding claims, comprising a further step of setting the induction frequency of a LF induction coil in the induction thermal processor between 1 kHz and 500 kHz.

12. The method according to any of the preceding claims, comprising a further step of setting the temperature in the induction thermal processor between 900 degrees Centigrade and 1200 degrees Centigrade.

13. A carbon black product obtainable by the process of claim 2.

14. A carbon black product according to claim 13 comprising a composition of 95% carbon, 2% silicon and 3% zinc oxide by weight.

15. A system for converting waste tyres into syngas and carbon black comprising

means for comminuting rubber from waste tyres into a powder;

a feeding system for feeding said powder into a powder injector;

a powder injector for injecting said powder into an induction thermal processor; and

an induction thermal processor for producing syngas and carbon black.

16. The system according to claim 15, further comprising a source of carrier gas connected to said feeding system.

17. The system according to claim 15, wherein said powder injector comprising a plasma torch and an RF induction coil.

18. The system according to claim 17, wherein said powder is introduced into the plasma torch of said powder injector.

19. The system according to claim 17, wherein said plasma torch comprises a metal tube in which a plasma stream is created.

20. The system according to claim 19, wherein said metal tube is made of copper.

21. The system according to claim 17, wherein said plasma torch comprises a quartz tube in which a plasma stream is created

22. The system according to claim 21, wherein said quartz tube is shielded by a metal shield.

23. The system according to claim 21, wherein said quartz tube is shielded by a water-cooled metal shield.

24. The system according to claim 22 or claim 23, wherein said metal shield is made of a non-magnetic material.

25. The system according to claim 15, wherein said induction thermal processor comprises a chamber and a LF induction coil.

26. The system according to claim 25, wherein said chamber comprises a

metal tube.

27. The system according to claim 26, wherein said metal tube is made of ferromagnetic material.

28. The system according to claim 26, wherein said metal tube is made of steel, preferably of stainless steel, graphite or carbon steel.

29. The system according to claim 26, wherein said metal tube is coated with a ferromagnetic material.

30. The system according to claim 26, wherein said metal tube is ceramic coated.

31. The system according to claim 26, wherein said metal tube is graphite coated.

32. The system according to claim 25, wherein said chamber is rotatable.

33. The system according to claim 25, wherein said LF induction coil is rotatable.

34. The system according to claim 25, wherein the longitudinal axis of the chamber is at an angle to the longitudinal axis of said powder injector.

35. The system according to claim 25, wherein the longitudinal axis of the LF induction coil is at an angle to the longitudinal axis of said powder injector.

36. The system according to claim 35, wherein said angle is between 0 and 90 degrees.

37. The system according to claim 16, wherein the source provides the carrier gas selected from the group comprising of argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.

38. The system according to claim 17, wherein said plasma torch uses gas that is selected from the group comprising of argon, nitrogen, neon, helium, carbon dioxide, or a mixture of two or more thereof.

39. The system according to claim 25, wherein the induction frequency of the LF induction coil is between 1 kHz and 500 kHz.

40. The system according to any of the preceding claims, wherein said feeding system has a feeder rate of between 1kg per hour and 2 tonnes per hour to said powder injector.

41. The system according to any of the preceding claims, wherein the temperature in the induction thermal processor is between 900 degrees Centigrade and 1200 degrees Centigrade.

42. The system according to any of the preceding claims, wherein the temperature in the powder injector is between 6000 degrees Centigrade and 11000 degrees Centigrade.

43. The system according to any of the preceding claims, wherein said powder used in the feeding system has a particle size ranging from 100 microns to 25mm.

44. A plasma reactor for converting rubber to syngas and carbon black comprising:

an enclosed chamber with an inlet and an outlet;

a plasma jet formed by passing a plasma gas through an RF induction

coil, said plasma jet positioned proximal to said inlet; and

a LF induction coil positioned proximal to said inlet but distal to said plasma jet;

wherein syngas and carbon black are obtained from said chamber.

45. A plasma reactor according to claim 44, wherein a carrier gas is introduced into the chamber using said inlet.