

In conventional tubular reactors heat is thus delivered to the reaction zone through the reactor walls.

Other than tubular furnaces solutions for pyrolysis equipment are known. Those include rotary reactors with complicated rotor blade arrangement. Costs for building and maintaining such equipment are higher than the profits that could be ever obtained by means thereof.

Traditional process for producing low-molecular weight hydrocarbons by thermal degradation thus encounters the following problems: 1. poor performance factor for tubular furnace reactors; 2. loss of valuable feedstock material; 3. long reaction times; 4. high secondary reactions rates; 4. high energy consumption; 5. non-optimum (less than possible) product yield and selectivity.

SUMMARY OF THE INVENTION

Embodiments of the invention alleviate above mentioned problems by implementing a novel method of thermal, thermo-chemical or catalytic thermo-chemical processing of feedstock, such as thermal cracking of hydrocarbon-containing compounds.

Embodiments of the present invention, herein provide a rotary machine type reactor suitable for the pyrolysis of hydrocarbon-containing feedstock.

According to a first aspect of the present invention, there is provided a shock wave reactor for thermal cracking of hydrocarbon-containing feedstock, comprising: a casing wherein a duct is formed with at least one inlet and at least one outlet; a rotor the periphery of which contains an axial-flow blade cascade; wherein the casing substantially encloses the periphery of the rotor and a number of stationary vane cascades inside the duct, wherein the cascades are configured to direct feedstock containing process stream to repeatedly pass said cascades in accordance with helical trajectory while propagating within the duct between the inlet and outlet and to generate stationary shock-waves to heat the feedstock, and wherein the reactor comprises a number of catalytic surfaces.

According to a second aspect of the present invention, there is provided the use of the above reactors in executing at least one procedure selected from the group consisting of: processing hydrocarbon feedstock containing medium and light weight hydrocarbon fractions; processing gaseous, oxygen-containing, fatty acid-based feedstock material; processing gaseous, fatty-acid based feedstock material, which material is preprocessed pine oil; processing gaseous cellulose-derived, and in particular, lignocellulose-derived feedstock material; and fast pyrolysis process comprising converting biomass-derived feedstock material into oil.

According to a third aspect of the present invention, there is provided a reactor assembly, comprising at least one of the above reactors and at least one further element selected from the group consisting of: a drive engine, a heat recovery unit, a quenching unit, a pyrolysis furnace, a pyrolysis furnace with external heating, a pre-heating apparatus or an air filter.

According to a fourth aspect of the present invention, there is provided a pyrolysis plant comprising at least two of the above reactors, functionally connected in series or in parallel.

According to a fifth aspect of the present invention, there is provided a method for thermal, thermo-chemical or catalytic thermo-chemical processing of feedstock matter comprising: obtaining a shock wave reactor having a casing wherein a duct is formed with at least one inlet and at least one outlet, further having a rotor, the periphery of which contains an axial-flow blade cascade, wherein the casing substantially encloses the periphery of the rotor and a number of stationary vane cascades inside the duct; elevating the rotation speed of the rotor to reach a predetermined process speed or speed range; feeding the feedstock containing process stream into the inlet port, whereupon both stationary cascades and the rotor cascade begin directing the feedstock containing process stream to repeatedly pass through said cascades in accordance with helical trajectory while propagating within the duct between the inlet and outlet ports, and sequentially generating stationary shock-waves to heat the feedstock stream within the reactor, causing thermal degradation or pyrolysis thereof, and directing the pyrolyzed product stream through the outlet port to a predetermined post-processing unit.

According to a sixth aspect of the present invention, there is provided a method for importing energy for fast endothermic- or fast exothermic catalytic reaction produced from mechanical energy of rotating blade cascades, said method comprising: obtaining a shock wave reactor comprising a number of catalytic surfaces and passing a preheated, feedstock containing gaseous phase into the reactor to carry out endothermic gaseous phase reactions, wherein the heat is provided by impulses, generated by shock waves resulting from mechanical energy derived from rotation of internal rotor blades.

In one embodiment, the helical-path reactor comprises a rotor with a shaft and a disk provided with blades forming an axial-flow rotor blade cascade, a stationary directing ring-shaped rim optionally provided with at least two stationary vane cascades adjoining the axial-flow rotor cascade, and a casing. The outer surface of the directing rim arranged within the casing substantially defines the duct with the inner surface of the casing to remain there between. Alternatively, at least some of the stationary vane cascades could be formed on the duct wall-defining inner surface of the casing, for example. Cross-section of the duct in the meridian plane forms a ring-shaped profile.

The duct may comprise several dividing partitions arranged in such a way to create several operational chambers. Operational chambers are preferably of equal size; however, other technical implementations are possible whether appropriate.

The reactor comprises at least one inlet port for feedstock stream and at least one outlet port for product stream. The inlet port is preferably arranged after each dividing partition in the direction of rotation of the rotor and the outlet port is preferably arranged before the dividing partition. The inlet and outlet ports may be integrated within the duct.

Claims

1. A shock wave reactor for thermal cracking of hydrocarbon-containing feedstock, comprising:
 - a casing wherein a duct is formed with at least one inlet and at least one outlet;
 - a rotor the periphery of which contains an axial-flow blade cascade;
 - wherein the casing substantially encloses the periphery of the rotor and a number of stationary vane cascades inside the duct,
 - wherein the cascades are configured to direct feedstock containing process stream to repeatedly pass said cascades in accordance with helical trajectory while propagating within the duct between the inlet and outlet and to generate stationary shock-waves to heat the feedstock, and
 - wherein the reactor comprises a number of catalytic surfaces.
2. The reactor of claim 1, wherein the duct has a substantially ring-shaped meridian section.
3. The reactor of any preceding claim, wherein the stationary vane cascades comprise at least two cascades, the first stationary vane cascade being configured upstream and the second stationary vane cascade being configured downstream the axial-flow blade cascade.
4. The reactor of claim 3, wherein the stationary vane cascades are arranged such that a vaneless space is created between the first cascade entrance point and second cascade exit point.
5. The reactor of any preceding claim, comprising a stationary directing rim inside the casing, the outer surface of which rim substantially defines the duct to remain therebetween with the inner surface of the casing.
6. The reactor of claim 5, wherein the outer surface of the rim is provided with at least some of the stationary vane cascades.
7. The reactor of any preceding claim, wherein the cascades are substantially adjacent inside the duct.
8. The reactor of any preceding claim, provided with two inlet ports and two outlet ports.
9. The reactor of claim 1, wherein the duct is configured to define a substantially conical, truncated cone- or cylindrical-shaped chamber.

10. The reactor of claim 9, wherein blades of the axial-flow rotor cascade(s) are configured to alternate with vanes of corresponding stationary vane cascades in longitudinal direction of the rotor forming sequential cascading units, each unit comprising rotor blade spatially located between stationary vanes.
11. The reactor of claim 9 or 10, wherein the first stationary vane cascade comprises a plurality of nozzle vanes and the second stationary vane cascade comprises a plurality of diffusing vanes, said nozzle and diffusing vanes being configured to mutually alternate in longitudinal direction of the rotor.
12. The reactor of any preceding claim, wherein the axial-flow blade cascade is configured to provide kinetic energy and to add velocity to feedstock containing process stream, and at least one stationary vane cascade is configured to reduce the velocity of the stream and convert kinetic energy into heat.
13. The reactor of any preceding claim, wherein the flow velocity of the feedstock containing process stream is supersonic at the cascades and subsonic in the vaneless space within the duct.
14. The reactor of any preceding claim, wherein at least some of the stationary vane cascades are arranged on the duct wall-defining inner surface of the casing.
15. The reactor of any preceding claim, wherein inlet and outlet ports are integrated within the duct.
16. The reactor of any preceding claim, wherein at least two dividing partitions are arranged within the duct symmetrically relative to a rotor axis so as to form at least two substantially identical operational chambers, each being associated with inlet and exit for the process stream.
17. The reactor of any preceding claim, wherein the first stationary vane cascade comprises a plurality of nozzle vanes having a curved profile and being disposed by their convex sides in the direction of rotor rotation, and wherein the second stationary vane cascade comprises a plurality of diffusing vanes having a curved supersonic compressor profile and being disposed by convex sides in the direction of rotor rotation.

18. The reactor of any preceding claim, wherein the axial-flow blade cascade contains a plurality of blades having a profile of active turbine blade, the blades being installed by concave side thereof in the direction of rotor rotation.
19. The reactor of any preceding claim, configured to process gasified carbohydrate-containing feedstock matter.
20. The reactor of any preceding claim, configured to process gasified glyceride-containing feedstock matter.
21. The reactor of any preceding claim, configured to process gasified preprocessed cellulosic biomass material.
22. The reactor of any preceding claim, wherein the catalytic surface(s) are formed by catalytic coating of at least several of the individual blades or vanes within the reaction zone and/or by catalytic coating of the duct wall-defining inner surface of the casing.
23. The reactor of any preceding claim, comprising a number of catalytic modules defined by ceramic or metallic substrate(s) or support carrier(s) with an active coating.
24. The reactor of claim 23, wherein the catalytic modules are realized as monolithic honeycomb structures.
25. The reactor of any preceding claim, wherein the reactor contains intermediate cooling or heating element.
26. The reactor of any preceding claim, where the reactor is configured for intermediate injection of diluent or reactive material.
27. The reactor of any preceding claim, configured such that the time gaseous feedstock spends in the reaction zone is substantially equal or less than about 10 milliseconds.
28. Use of the reactor of any preceding claim in executing at least one procedure selected from the group consisting of: processing hydrocarbon feedstock containing medium and light weight hydrocarbon fractions; processing gaseous, oxygen-containing, fatty acid-based feedstock material; processing gaseous, fatty-acid based feedstock material, which material is preprocessed pine oil; processing gaseous cellulose-derived, and in particular, lignocellulose-

derived feedstock material; and fast pyrolysis process comprising converting biomass-derived feedstock material into oil.

29. A reactor assembly, comprising at least one reactor according to any of claims 1-27 and at least one further element selected from the group consisting of: a drive engine, a heat recovery unit, a quenching unit, a pyrolysis furnace, a pyrolysis furnace with external heating, a pre-heating apparatus or an air filter.

30. A pyrolysis plant comprising at least two reactors according to any of claims 1-27, functionally connected in series or in parallel.

31. A method for thermal, thermo-chemical or catalytic thermo-chemical processing of hydrocarbon-containing feedstock matter comprising:

a. obtaining a shock wave reactor having a casing wherein a duct is formed with at least one inlet and at least one outlet, further having a rotor, the periphery of which contains an axial-flow blade cascade, wherein the casing substantially encloses the periphery of the rotor and a number of stationary vane cascades inside the duct;

b. elevating the rotation speed of the rotor to reach a predetermined process speed or speed range;

c. feeding the feedstock containing process stream into the inlet port, whereupon both stationary cascades and the rotor cascade begin directing the feedstock containing process stream to repeatedly pass through said cascades in accordance with helical trajectory while propagating within the duct between the inlet and outlet ports, and sequentially generating stationary shock-waves to heat the feedstock stream within the reactor, causing thermal degradation or pyrolysis thereof, and

d. directing the pyrolyzed product stream through the outlet port to a predetermined post-processing unit.

32. The method of claim 31, wherein the method is applied for thermal cracking of hydrocarbon-containing feedstock.

33. The method of claim 31 or 32, wherein the duct has a substantially ring- shaped meridian section.

34. The method of any of claims 31-33, wherein the feedstock comprises medium or light weight hydrocarbon fractions.

35. The method of any of claims 31-34, wherein the feedstock is cellulose-derived or, in particular, lignocellulose-derived preprocessed biomass, supplied into the reactor in substantially gaseous form.
36. A method for importing energy for fast endothermic- or fast exothermic catalytic reaction produced from mechanical energy of rotating blade cascades, said method comprising:
- a. obtaining a shock wave reactor comprising a number of catalytic surfaces and
 - b. passing a preheated, feedstock containing gaseous phase into the reactor to carry out endothermic gaseous phase reactions,
- wherein the heat is provided by impulses, generated by shock waves resulting from mechanical energy derived from rotation of internal rotor blades.
37. The method of claim 36, wherein the feedstock comprises medium or light weight hydrocarbon fractions.
38. The method of claim 36 or 37, wherein the feedstock is cellulose-derived or, in particular, lignocellulose-derived preprocessed biomass, supplied into the reactor in substantially gaseous form.