Claims:

1. A method of hydrotreatment, the method comprising the steps of:

providing a material that is suitable for undergoing hydrotreatment;

mixing the material with a hydrogenation agent to form a feed stream comprising a mixture of the material and the hydrogenation agent; and

heating the feed stream to break chemical bonds of the material in the presence of a catalyst, the feed stream being heated to at least a temperature at which the catalyst can provide activated hydrogen to react with the broken bonds within the material so as to minimise coke formed from the material.

2. The method of claim 1, wherein the hydrogenation agent is hydrogen or a hydrogen-containing reactant.

3. The method of claim 1 or claim 2, wherein the feed stream is heated upon contact with the catalyst, the catalyst having been heated to at least the temperature at which the catalyst can provide activated hydrogen to react with the broken bonds within the material so as to minimise coke formed from the material.

4. The method of any one of the preceding claims, further comprising the step of, prior to heating the feed stream in the presence of the catalyst, maintaining the feed stream below a predefined temperature at which an amount of coke formed from the material would substantially reduce activity of the catalyst.

5. The method of claim 4, wherein the feed stream is maintained below the predefined temperature by mixing the hydrogenation agent with the material such that the feed stream has a linear velocity sufficient to reduce a residence time of the material in a first region, which is at or above the predefined temperature, prior to contacting the catalyst in a second region.

6. The method of claim 4 or claim 5, wherein the feed stream is maintained below the predefined temperature by directing the feed stream directly into the second region.

7. The method of claim 6, wherein the feed stream is directed through a passage that is provided with a feed stream outlet from which the feed stream can flow, the feed stream outlet being arranged at or adjacent the second region such that at least a portion of the feed stream flowing from the feed stream outlet flows directly into the second region.

8. The method of claim 7, wherein a fluid dispersing device is provided at the feed stream outlet so as to disperse or atomise the feed stream as the feed stream flows through the feed stream outlet.

9. The method of any one of the preceding claims further comprising the steps of:

directing the feed stream to contact the catalyst such that the feed stream at least partially reacts in the presence of the catalyst to form a product stream; and

transferring heat from the product stream to the feed stream.

10. The method of claim 9, wherein a hydrogen stream is used to transfer heat from the product stream to the feed stream.

11. The method of claim 10, wherein the hydrogen stream is directed such that at least a portion of the hydrogen stream obtains heat from a heat exchanger through which the product stream flows.

12. The method of claim 10 or claim 11, wherein heat obtained by the hydrogen stream is transferred to the feed stream by mixing the hydrogen stream with the feed stream.

13. The method of any one of claims 10 to 12, wherein the hydrogen stream is used in the reaction in the presence of the catalyst.

14. The method of any one of claims 9 to 13, wherein the feed stream passes through a first region to react in a second region, and the resulting product stream is directed to the first region where heat is transferred from the product stream to the feed stream.

15. The method of claim 14, wherein the first and second regions are internal to a reactor.

16. The method of claim 14, wherein at least a portion of the first region is external to a reactor, and the second region is internal to the reactor

17. The method of any one of claims 14 to 16, wherein the product stream is directed to the first region via the second region.

18. The method of any one of the preceding claims, wherein the material is bio-crude.

19. The method of any one of claims 1 to 17, wherein the material is a biological material, a pharmaceutical material, or any material that can be hydrotreated but that can undergo undesirable reactions in the absence of activated hydrogen provided by a catalyst.

20. The method of any one of the preceding claims, wherein the catalyst is a nickel-based catalyst or a cobalt-based catalyst.

21. The method of claim 20, wherein the catalyst is a NiMo catalyst pre-sulphided or sulphided in situ, or a CoMo catalyst pre-sulphided or sulphided in situ.

22. The method of claim 21, wherein the catalyst contains catalytic species that can catalyse the *in situ* formation of activated hydrogen from the feed material and/or hydrogenation agent.

23. A method of hydrotreatment, the method comprising the steps of:

directing a feed stream to contact a catalyst such that the feed stream at least partially reacts in the presence of the catalyst to form a product stream, the feed stream comprising a material that is suitable for undergoing hydrotreatment and a hydrogenation agent; and

transferring heat from the product stream to the feed stream.

24. The method of claim 23, wherein the hydrogenation agent is hydrogen or a hydrogen-containing reactant.

25. The method of claim 23 or claim 24, wherein the feed stream comprises water and wherein transferring heat from the product stream to the feed stream facilitates evaporating at least a portion of the water of the feed stream.

26. The method of any one of claims 23 to 25, wherein a hydrogen stream is used to transfer heat from the product stream to the feed stream.

27. The method of claim 26, wherein the hydrogen stream is directed such that at least a portion of the hydrogen stream obtains heat from a heat exchanger through which the product stream flows.

28. The method of claim 26 or claim 27, wherein heat obtained by the hydrogen stream is transferred to the feed stream by mixing the hydrogen stream with the feed stream.

29. The method of any one of claims 26 to 28, wherein the hydrogen stream is used in the reaction in the presence of the catalyst.

30. The method of any one of claims 23 to 29, wherein the feed stream passes through a first region to react in a second region in which the catalyst is located, and the resulting product stream is directed to the first region where heat is transferred from the product stream to the feed stream.

31. The method of claim 30, wherein the first and second regions are internal to a reactor.

32. The method of claim 31, wherein at least a portion of the first region is external to the reactor, and the second region is internal to the reactor.

33. The method of any one of claims 30 to 32, wherein the product stream is directed to the first region from or via the second region.

34. The method of any one of claims 23 to 33, further comprising the step of heating the feed stream to break chemical bonds of the material in the presence of a catalyst, the feed stream being heated to at least a temperature at which the catalyst can provide activated hydrogen to react with the broken bonds within the material so as to minimise coke formed from the material.

35. The method of claim 34, further comprising the step of, prior to heating the feed stream in the presence of the catalyst, maintaining the feed stream below a

predefined temperature at which an amount of coke formed from the material would substantially reduce activity of the catalyst.

36. The method of claim 35, wherein the feed stream is maintained below the predefined temperature by mixing the hydrogenation agent with the material such that the feed stream has a linear velocity sufficient to reduce a residence time of the material in a first region prior to contacting the catalyst in a second region.

37. The method of claim 35 or claim 36, wherein the feed stream is maintained below the predefined temperature by directing the feed stream directly into the second region.

38. The method of claim 37, wherein the feed stream is directed through a passage that is provided with a feed stream outlet from which the feed stream can flow, the feed stream outlet being arranged at or adjacent the second region such that at least a portion of the feed stream flowing from the feed stream outlet flows directly into the second region.

39. The method of claim 38, wherein a fluid dispersing device is provided at the feed stream outlet so as to disperse or atomise the feed stream as the feed stream flows through the feed stream outlet.

40. The method of claim 39, wherein the fluid dispersing device is a distributor or an atomizer.

41. The method of any one of claims 23 to 40, wherein the material is bio-crude.

42. The method of any one of claims 23 to 40, wherein the material is a biological material, a pharmaceutical material, or any material that can be

hydrotreated but that can undergo undesirable reactions in the absence of activated hydrogen provided by a catalyst.

43. The method of any one of claims 23 to 42, wherein the catalyst is a nickel-based catalyst or a cobalt-based catalyst.

44. The method of claim 43 wherein the catalyst is a NiMo catalyst pre-sulphided or sulphided in situ, or the catalyst is a CoMo catalyst pre-sulphided or sulphided in situ.

45. The method of claim 44, wherein the catalyst contains catalytic species that can catalyse the *in situ* formation of activated hydrogen from the feed material and/or hydrogenation agent.

46. A hydrotreatment system comprising:

a reaction region in which a catalyst is located;

a first input for providing a material that is suitable for undergoing hydrotreatment;

a second input for providing a hydrogenation agent stream for forming a feed stream when mixed with the material, the feed stream comprising a mixture of the material and the hydrogenation agent;

a feed stream passage arranged to receive the material and the hydrogen stream, the feed stream passage further being arranged to direct the resulting feed stream to the reaction region in which the catalyst is located; and

a heat source for providing heat to the reaction region so as to heat the feed stream to break chemical bonds of the material in the presence of the catalyst, the feed stream being heated to at least a temperature at which the catalyst can provide activated hydrogen to react with the broken bonds within the material so as to minimise coke formed from the material.

an outlet stream passage for products and any unreacted components of the feed stream to exit the hydrotreatment system.

47. The system of claim 46, wherein the hydrogenation agent is hydrogen or a hydrogen-containing reactant.

48. The system of claim 46 or claim 47, wherein the heat source is provided by exothermic reactions that occur during hydrotreatment of the material.

49. A hydrotreatment system comprising:

a reaction region in which a catalyst is located;

a feed stream passage arranged to direct a feed stream to contact the catalyst located in the reaction region such that the feed stream at least partially reacts in the presence of the catalyst to form a product stream, the feed stream comprising a material that is suitable for undergoing hydrotreatment and a hydrogenation agent

a heat exchanger arranged to receive the product stream and to transfer heat from the product stream to the feed stream; and

an outlet stream passage for products and any unreacted components of the feed stream to exit the hydrotreatment system.

50. The hydrotreatment system of claim 49, wherein the hydrogenation agent is hydrogen or a hydrogen-containing reactant.

51. The system of any one of claims 46 to 50, wherein the material is bio-crude.

52. The system of any one of claims 46 to 50, wherein the material is a biological material, a pharmaceutical material, or any material that can be hydrotreated but that can undergo undesirable reactions in the absence of activated hydrogen provided by a catalyst.

53. The system of any one of claims 46 to 52, wherein the catalyst is a NiMo catalyst pre-sulphided or sulphided in situ, or the catalyst is a CoMo catalyst pre-sulphided or sulphided in situ.

54. The system of claim 53, wherein the catalyst contains catalytic species that can catalyse the *in situ* formation of activated hydrogen from the feed material and/or hydrogenation agent.

55. The system of any one of claim 46 to 54, wherein the system is a component of a further system, such as a petro-refinery system.

Claims:

1. A method of hydrotreatment, the method comprising the steps of:

providing a material that is suitable for undergoing hydrotreatment;

mixing the material with a hydrogenation agent to form a feed stream comprising a mixture of the material and the hydrogenation agent;

maintaining the feed stream below a predefined temperature at which an amount of coke formed from the material would substantially reduce activity of the catalyst; thereafter

heating the feed stream to break chemical bonds of the material only in the presence of a catalyst contained in a reactor, the catalyst being arranged to provide active hydrogen, wherein the feed stream is heated to break the chemical bonds of the material and is in contact with the catalyst only after the catalyst has been heated to at least a temperature at which the catalyst can provide activated hydrogen to react with broken bonds within the material to form a product stream.

2. The method of claim 1, wherein the hydrogenation agent is hydrogen or a hydrogen-containing reactant.

3. The method of any one of the preceding claims wherein the predefined temperature is 150°C.

4. The method of any one of the preceding claims, wherein the feed stream passes through a first region into a second region, the first region being at or above the predefined temperature and the second region containing the catalyst, wherein the feed stream is maintained below the predefined temperature while passing through the first region by mixing the hydrogenation agent with the material such that the feed stream has a linear velocity sufficient to reduce a residence time of the feed stream in the first region.

5. The method of claim 4, wherein the feed stream is maintained below the predefined temperature by directing the feed stream directly into the second region.

6. The method of claim 5, wherein the feed stream is directed through a passage that is provided with a feed stream outlet from which the feed stream can flow, the feed stream outlet being arranged at or adjacent the second region such that at least a portion of the feed stream flowing from the feed stream outlet flows directly into the second region.

7. The method of claim 6, wherein a fluid dispersing device is provided at the feed stream outlet so as to disperse or atomise the feed stream as the feed stream flows through the feed stream outlet.

8. The method of claim 7, wherein the fluid dispersing device is a distributor or an atomizer.

9. The method of any one of the preceding claims further comprising the step of transferring heat from the product stream to the feed stream.

10. The method of claim 9, wherein a hydrogen stream is used to transfer heat from the product stream to the feed stream.

11. The method of claim 10, wherein the hydrogen stream is directed such that at least a portion of the hydrogen stream obtains heat from a heat exchanger through which the product stream flows.

12. The method of claim 10 or claim 11, wherein heat obtained by the hydrogen stream is transferred to the feed stream by mixing the hydrogen stream with the feed stream.

13. The method of any one of claims 10 to 12, wherein the hydrogen stream is used in the reaction in the presence of the catalyst.

14. The method of any one of claims 9 to 13, wherein the feed stream passes through a first region to react in a second region, and the resulting product stream is directed to the first region where heat is transferred from the product stream to the feed stream.

15. The method of claim 14, wherein the first and second regions are internal to a reactor.

16. The method of claim 14, wherein at least a portion of the first region is external to a reactor, and the second region is internal to the reactor

17. The method of any one of claims 14 to 16, wherein the product stream is directed to the first region via the second region.

18. The method of any one of the preceding claims, wherein the material is bio-crude.

19. The method of any one of claims 1 to 17, wherein the material is a biological material, a pharmaceutical material, or any material that can be hydrotreated but that can undergo undesirable reactions in the absence of activated hydrogen provided by a catalyst.

20. The method of any one of the preceding claims, wherein the catalyst is a nickel-based catalyst or a cobalt-based catalyst.

21. The method of claim 20, wherein the catalyst is a NiMo catalyst pre-sulphided or sulphided in situ, or a CoMo catalyst pre-sulphided or sulphided in situ.

22. The method of claim 21, wherein the catalyst contains catalytic species that can catalyse the *in situ* formation of activated hydrogen from the feed material and/or hydrogenation agent.

23. The method of any one of claims 9 to 22, wherein the feed stream comprises water and wherein transferring heat from the product stream to the feed stream facilitates evaporating at least a portion of the water of the feed stream.

24. A hydrotreatment system comprising:

a reaction region in which a catalyst arranged to provide active hydrogen is located;

a first input for providing a material that is suitable for undergoing hydrotreatment;

a second input for providing a hydrogenation agent stream to be mixed with the material for forming a feed stream, the feed stream comprising a mixture of the material and the hydrogenation agent;

a feed stream passage arranged to receive the material and the hydrogen stream, the feed stream passage further being arranged to direct the resulting feed stream to the reaction region in which the catalyst is located;

a heat source for providing heat to the reaction region and arranged to pre-heat the reaction region and the catalyst to a hydrotreatment temperature, whereby the feed stream is arranged to contact the pre-heated catalyst and be heated to the hydrotreatment temperature only in the presence of the catalyst, the heating of the feed stream being arranged to break chemical bonds within the material and enabling the activated hydrogen to react with the broken chemical bonds within the material so as to form a product stream, and

an outlet stream passage for the product stream and any unreacted components of the feed stream to exit the hydrotreatment system,

wherein, prior to the feed stream being in the presence of the catalyst, the feed stream is maintained below a predefined temperature at which the chemical bonds within the material will break.

25. The system of claim 24, wherein the hydrogenation agent is hydrogen or a hydrogen-containing reactant.

26. The system of claim 24 or claim 25, wherein the heat source is provided by exothermic reactions that occur during hydrotreatment of the material.

27. The system of any one of claims 24 to 26, comprising a heat exchanger arranged to receive the product stream for transferring heat from the product stream to the feed stream.

28. The system of any one of claims 24 to 27, wherein the predefined temperature is 150°C.

29. The system of any one of claims 24 to 28, wherein the material is bio-crude.

30. The system of any one of claims 24 to 28, wherein the material is a biological material, a pharmaceutical material, or any material that can be hydrotreated but that can undergo undesirable reactions in the absence of activated hydrogen provided by a catalyst.

31. The system of any one of claims 24 to 30, wherein the catalyst is a NiMo catalyst pre-sulphided or sulphided in situ, or the catalyst is a CoMo catalyst pre-sulphided or sulphided in situ.

32. The system of claim 31, wherein the catalyst contains catalytic species that can catalyse the *in situ* formation of activated hydrogen from the feed material and/or hydrogenation agent.

33. The system of any one of claim 24 to 32, wherein the system is a component of a further system, such as a petro-refinery system.