SUMMARY

It has been found that the process and HER reactor used herein for CO_2 shift provide a much lower risk of metal dusting compared to a heat exchange steam methane reformer.

The invention is as defined in the independent claims.

In one aspect of the present disclosure, there is provided a process for converting a first gas feed comprising CO_2 and H_2 to a synthesis gas stream, via a CO_2 shift reaction of said first gas feed in a heat exchange reactor, HER, said HER comprising

at least one process side and at least one heating side, wherein the process side of the HER comprises a process side inlet and a process side outlet,

wherein the process side of the HER comprises a first reaction zone (I) disposed closest to the process side inlet,

and wherein process side of the HER comprises a second reaction zone (II) disposed closest to the process side outlet,

wherein the heating side of the HER comprises a heating side inlet and – optionally – a heating side outlet,

said at least one process side and said at least one heating side, being arranged such that heat transfer from heating side to at least a part of said process side is possible,

said process comprising the steps of:

- supplying the first gas feed to the process side of the HER via said process side inlet;
- supplying a heating fluid to the heating side of the HER via said heating side inlet, and allowing heat transfer from said heating fluid to the process side of the HER;
- carrying out an overall exothermic reaction of said first gas feed in the first reaction zone (I), wherein the overall exothermic reaction comprises at least the following reactions, which have a net progress from left to right:

$CO\ (g) + 3\ H_2\ (g) \leftrightarrows CH_4\ (g) + H_2O\ (g)$ (2)

$CO_2\ (g) + H_2\ (g) \leftrightarrows CO\ (g) + H_2O\ (g)$ (1);

- carrying out an overall endothermic reaction of gas from said first reaction zone (I) in the second reaction zone (II), wherein the overall endothermic reaction comprises at least the following reactions, which have a net progress from left to right:

  CH_4 (g) + H_2O ⇆ CO (g) + $3H_2$ (g) (reverse of (2))

  CO_2 (g) + H_2 (g) ⇆ CO (g) + H_2O (g) (1)

- outletting the synthesis gas stream from the process side via the process side outlet; optionally in admixture with a cooled fluid, and

optionally outletting a cooled fluid from said heating side, via the heating side outlet.

In another aspect of the present disclosure, there is provided a heat exchange reactor (HER), for converting a first gas feed comprising CO_2 and H_2 to a synthesis gas stream, via a CO_2 shift reaction of said first gas feed, said HER comprising:

at least one process side and at least one heating side, wherein the process side of the HER comprises a process side inlet and a process side outlet,

said process side inlet being arranged to supply said first gas feed comprising CO_2 and H_2 to said process side,

said process side outlet being arranged to output said synthesis gas stream from said process side, optionally in admixture with a cooled fluid,

wherein the process side of the HER comprises a first reaction zone (I) disposed closest to the process side inlet,

and wherein process side of the HER comprises a second reaction zone (II) disposed closest to the process side outlet,

wherein the first reaction zone (I) is arranged to carry out an overall exothermic reaction of said first gas feed, wherein the overall exothermic reaction comprises at least the following reactions, which have a net progress from left to right:

CO (g) + 3 H_2 (g) ⇆ CH_4 (g) + H_2O (g) (2)

CO_2 (g) + H_2 (g) ⇆ CO (g) + H_2O (g) (1),

wherein the second reaction zone (II) is arranged to carry out an overall endothermic reaction of gas from said first reaction zone (I), wherein the overall endothermic reaction comprises at least the following reactions, which have a net progress from left to right:

CH_4 (g) + H_2O ⇆ CO (g) + $3H_2$ (g) (reverse of)

CO_2 (g) + H_2 (g) ⇆ CO (g) + H_2O (g) (1),

wherein the heating side of the HER comprises a heating side inlet and – optionally - a heating side outlet,

said heating side inlet being arranged to supply a heating fluid to said heating side,

optionally, wherein said heating side outlet being arranged to output a cooled fluid from said heating side,

said at least one process side and said at least one heating side, being arranged such that heat transfer from heating side to at least a part of process side is possible.

In one example, a process for converting a first gas feed comprising CO_2 and H_2 to a synthesis gas stream, via a CO_2 shift reaction of said first gas feed in a heat exchange reactor, HER is provided, wherein said HER comprises:

at least one process side and at least one heating side, wherein the process side of the HER comprises a process side inlet and a process side outlet,

wherein the process side of the HER comprises a first reaction zone (I) disposed closest to the process side inlet,

and wherein process side of the HER comprises a second reaction zone (II) disposed closest to the process side outlet,

wherein the heating side of the HER comprises a heating side inlet and - optionally – a heating side outlet,

said at least one process side and said at least one heating side, being arranged such that heat transfer from heating side to at least a part of the process side is possible,

said process comprising the steps of:

- supplying the first gas feed to the process side of the HER via said process side inlet;
- supplying a heating fluid to the heating side of the HER via said heating side inlet, and allowing heat transfer from said heating fluid to the process side of the HER;
- carrying out an overall exothermic reaction of said first gas feed in the first reaction zone (I), wherein the overall exothermic reaction comprises at least the following reactions, which have a net progress from left to right:

$CO\ (g) + 3\ H_2\ (g) \leftrightarrows CH_4\ (g) + H_2O\ (g)$ (2)

$CO_2\ (g) + H_2\ (g) \leftrightarrows CO\ (g) + H_2O\ (g)$ (1);

CLAIMS

1. A process for converting a first gas feed comprising CO_2 and H_2 to a synthesis gas stream, via a CO_2 shift reaction of said first gas feed in a heat exchange reactor, HER, said HER comprising

at least one process side and at least one heating side, wherein the process side of the HER comprises a process side inlet and a process side outlet,

wherein the process side of the HER comprises a first reaction zone (I) disposed closest to the process side inlet,

and wherein process side of the HER comprises a second reaction zone (II) disposed closest to the process side outlet,

wherein the heating side of the HER comprises a heating side inlet and – optionally – a heating side outlet,

said at least one process side and said at least one heating side, being arranged such that heat transfer from heating side to at least a part of said process side is possible,

said process comprising the steps of:

- supplying the first gas feed to the process side of the HER via said process side inlet;
- supplying a heating fluid to the heating side of the HER via said heating side inlet, and allowing heat transfer from said heating fluid to the process side of the HER;
- carrying out an overall exothermic reaction of said first gas feed in the first reaction zone (I), wherein the overall exothermic reaction comprises at least the following reactions, which have a net progress from left to right:
  $CO\ (g) + 3\ H_2\ (g) \leftrightarrows CH_4\ (g) + H_2O\ (g)$ (2)
  $CO_2\ (g) + H_2\ (g) \leftrightarrows CO\ (g) + H_2O\ (g)$ (1);
- carrying out an overall endothermic reaction of gas from said first reaction zone (I) in the second reaction zone (II), wherein the overall endothermic reaction comprises at least the following reactions, which have a net progress from left to right:
  $CH_4\ (g) + H_2O \leftrightarrows CO\ (g) + 3H_2\ (g)$ (reverse of (2))
  $CO_2\ (g) + H_2\ (g) \leftrightarrows CO\ (g) + H_2O\ (g)$ (1)
- outletting the synthesis gas stream from the process side via the process side outlet; optionally in admixture with a cooled fluid, and

- optionally outletting a cooled fluid from said heating side, via the heating side outlet.

2. The process according to claim 1, wherein the temperature of the gas in the first reaction zone (I) is between 300-800°C.

3. The process according to any one of claims 1-2, wherein the temperature of the gas in the second reaction zone (II) is between 600-1200°C.

4. The process according to any one of the preceding claims, wherein the synthesis gas stream and the cooled fluid are combined to provide a third product stream.

5. The process according to any one of the preceding claims, wherein the heating fluid and at least a portion of the synthesis gas stream leaving the second reaction zone are combined internally in the HER and recycled as at least a part of the heating fluid.

6. The process according to any one of the preceding claims, wherein the process conditions are adjusted to provide a temperature of the synthesis gas stream and/or the cooled fluid, and/or the third product stream at the respective outlet of the HER which is higher than the critical limit for metal dusting.

7. The process according to any one of the preceding claims, wherein the cooled exit temperature of the synthesis gas stream and/or the cooled fluid and/or the third product stream is 500°C or higher, 600°C or higher, 700°C or higher, or 800°C or higher.

8. The process according to any one of the preceding claims, wherein the synthesis gas stream and/or the cooled fluid and/or the third product stream at said cooled exit temperature has a CO reduction reaction actual gas carbon activity lower than 100, or lower than 50, or lower than 10, or lower than 5, or lower than 1.

9. The process according to any one of the preceding claims, wherein the H_2/CO ratio of the synthesis gas stream and/or the cooled fluid and/or the third product stream is in the range from 0.5 to 3.0, such as in the range 1.9 – 2.1, or in the range 2 - 3.

10. The process according to any one of the preceding claims, wherein the $(H_2-CO_2)/(CO+CO_2)$ ratio of the synthesis gas stream and/or the cooled fluid and/or the third product stream is in the range from 1.5 to 2.5, such as in the range 1.9 – 2.1, or in the range 2 – 2.05.

11. The process according to any of the preceding claims, wherein the ratio between H_2 and CO_2 may be between 1-5, such as e.g. between 2-4, between 2-3 or between 2.2-2.5, or between 2.8-3.5, or between 2.8 and 3.2.

12. The process according to any of the preceding claims, wherein the molar ratio of CH_4/CO_2 in the first feed is preferably less than 0.5, such as less than 0.2, preferably less than 0.1.

13. The process according to any of the preceding claims, wherein the first gas feed additionally comprises methane, suitably up to 3 mole%, or up to 8 mole%, or up to 12 mole% methane.

14. The process according to any of the preceding claims, wherein the heating fluid is provided from an electrical RWGS (e-RWGS) reactor, a fired RWGS reactor or an autothermal RWGS reactor, preferably an electrical RWGS (e-RWGS) reactor.

15. The process according to any of the preceding claims, wherein the heating fluid comprises CO_2 and H_2.

16. A heat exchange reactor (HER), for converting a first gas feed comprising CO_2 and H_2 to a synthesis gas stream, via a CO_2 shift reaction of said first gas feed, said HER comprising:

at least one process side and at least one heating side, wherein the process side of the HER comprises a process side inlet and a process side outlet,

said process side inlet being arranged to supply said first gas feed comprising CO_2 and H_2 to said process side,

said process side outlet being arranged to output said synthesis gas stream from said process side, optionally in admixture with a cooled fluid,

wherein the process side of the HER comprises a first reaction zone (I) disposed closest to the process side inlet,

and wherein process side of the HER comprises a second reaction zone (II) disposed closest to the process side outlet,

wherein the first reaction zone (I) is arranged to carry out an overall exothermic reaction of said first gas feed, wherein the overall exothermic reaction comprises at least the following reactions, which have a net progress from left to right:

$CO\ (g) + 3\ H_2\ (g) \leftrightarrows CH_4\ (g) + H_2O\ (g)$ (2)

$CO_2\ (g) + H_2\ (g) \leftrightarrows CO\ (g) + H_2O\ (g)$ (1),

wherein the second reaction zone (II) is arranged to carry out an overall endothermic reaction of gas from said first reaction zone (I), wherein the overall endothermic reaction comprises at least the following reactions, which have a net progress from left to right:

$CH_4\ (g) + H_2O \leftrightarrows CO\ (g) + 3H_2\ (g)$ (reverse of)

$CO_2\ (g) + H_2\ (g) \leftrightarrows CO\ (g) + H_2O\ (g)$ (1),

wherein the heating side of the HER comprises a heating side inlet and – optionally - a heating side outlet,

said heating side inlet being arranged to supply a heating fluid to said heating side,

optionally, wherein said heating side outlet being arranged to output a cooled fluid from said heating side,

said at least one process side and said at least one heating side, being arranged such that heat transfer from heating side to at least a part of process side is possible.

17. The HER according to claim 16 or the process according to any one of claims 1-15, wherein the process side of the HER has a total length extending from the process side inlet to the process side outlet, and wherein the first reaction zone (I) has an extension of less than 50%, such as less than 30%, preferably less than 20%, more preferably less than 10% of the total length of the process side of the HER.

18. The HER according to any one of claims 16-17 or the process according to any one of claims 1-15, wherein a first catalyst is located at least in the first reaction zone (I) of the HER.

19. The HER according to any one of claims 16-18 or the process according to any one of claims 1-15, wherein at least an end section of the process side of the first reaction zone (I), which is located closest to the process side inlet of the HER, and which has an extension of up to 25% of the total extension of the process side of the first reaction zone (I) in the direction from the process side inlet towards the process side outlet, is not directly in contact with the heating side of the HER, so that this end section of the first reaction zone (I) is primarily heated by the adiabatic temperature rise caused by the exothermic reaction in the first reaction zone (I).

20. The HER according to any one of claims 16-19 or the process according to any one of claims 1-15, wherein the HER is a bayonet-type HER.

21. The HER according to any one of claims 16-20 or the process according to any one of claims 1-15, wherein the HER has at least two process sides.

22. The HER according to any one of claims 16-21 or the process according to any one of claims 1-15, wherein the HER has at least two heating sides.