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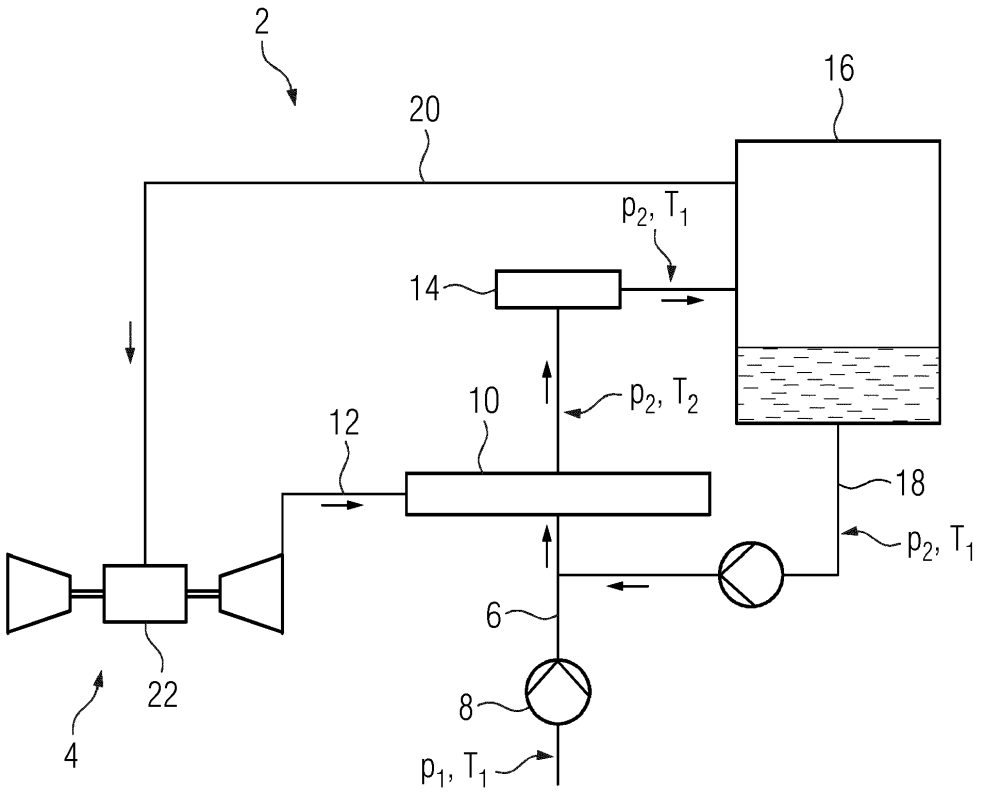
(71) Applicant: **Siemens Energy Global GmbH & Co. KG**
81739 München (DE)

(72) Inventor: **The designation of the inventor has not yet been filed**

(54) METHOD AND SYSTEM FOR PRODUCING A FUEL FOR DRIVING A GAS TURBINE

(57) The invention relates to a method for producing a fuel for driving a gas turbine, including the steps of:
- pressurizing liquid ammonia,
- the pressurized ammonia is fed by a feeding line (6) into an ammonia cracking device (10) and partially cracked using exhaust gas heat from the gas turbine (4),
- a mixture of hydrogen, nitrogen and ammonia is taken out of the ammonia cracking device (10) to a cooling unit and cooled down to ambient temperatures,
- in a gas-liquid-separator (16), the gaseous mixture of hydrogen, nitrogen and ammonia is separated from the liquid ammonia by means of centrifugal and/or gravitational forces,
- the gaseous mixture of hydrogen, nitrogen and ammonia is fed to at least one burner (22) of the gas turbine (4),
- the uncracked, liquid ammonia from the gas-liquid-separator (16) is mixed with the pressurized ammonia in the feeding line (6).

In this method the exhaust heat of the gas turbine is advantageously used in the cracking process.



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Description

[0001] Ammonia is a potential carrier of hydrogen fuel. However, it is not suitable to directly combust in a typical gas turbine burner, mainly due to low flammability, but also due to very high NOx emissions due to the fuel-bound nitrogen.

[0002] As of today, ammonia has been used in research kW-scale gas turbines. There is also prior art, WO 2017/160154, in the area of industrial gas turbines operating with ammonia. In detail, WO 2017/160154 discloses a process for generating power using a gas turbine, comprising the steps of: (i) vaporising and pre-heating liquid ammonia to produce pre-heated ammonia gas; (ii) introducing the pre-heated ammonia gas into an ammonia-ammonia cracking device suitable for converting ammonia gas into a mixture of hydrogen and nitrogen; (iii) converting the pre-heated ammonia gas into a mixture of hydrogen and nitrogen in the device; (iv) cooling the mixture of hydrogen and nitrogen to give a cooled hydrogen and nitrogen mixture; (v) introducing the cooled hydrogen and nitrogen mixture into a gas turbine; and (vi) combusting the cooled hydrogen and nitrogen mixture in the gas turbine to generate power. In the process described in WO 2017/160154, in the first place the liquid ammonia is preheated and vaporized to form gaseous ammonia. The gaseous ammonia is then fed to the cracker unit comprising a catalyst. In this case the heat exchanging device and the ammonia cracking device are two different units. Yet, the cracking reaction is endothermic and heat supply is necessary also during cracking of ammonia. In WO 2017/160154, the heat required for the cracking reaction is derived from redirecting 10-20% of the hydrogen/nitrogen fuel stream to the gas turbine.

[0003] The object of the invention is, therefore, to provide an improved method for producing a fuel for a gas turbine.

[0004] The object of the invention is achieved by the independent claims 1 and 6. The dependent claims describe advantageous developments and modifications of the invention.

[0005] In accordance with the invention there is provided a method for producing a fuel for driving a gas turbine, including the steps of:

- pressurizing liquid ammonia,
- the pressurized ammonia is fed by a feeding line into an ammonia cracking device and partially cracked using exhaust gas heat from the gas turbine,
- a mixture of hydrogen, nitrogen and ammonia is fed out of the ammonia cracking device to a cooling unit and cooled down to ambient temperature,
- in a gas-liquid-separator, the gaseous mixture of hydrogen, nitrogen and ammonia is separated from the liquid ammonia by means of centrifugal and/or gravitational forces,
- the gaseous mixture of hydrogen, nitrogen and ammonia is fed to at least one burner of the gas turbine,
- the uncracked, liquid ammonia from the gas-liquid-separator is mixed with the pressurized ammonia in the feeding line.

[0006] In accordance with the invention there is provided a system for producing a fuel for driving a gas turbine, comprising:

- a feeding line for liquid ammonia in which a pump is integrated,
- an ammonia cracking device arranged on the feeding line for the production of a mixture of hydrogen, nitrogen and ammonia and an exhaust gas line connecting an exit of the gas turbine with the ammonia cracking device,
- a cooling unit for cooling the mixture of hydrogen, nitrogen and ammonia down to ambient temperature,
- a gas-liquid-separator for the separation of the gaseous hydrogen, nitrogen and ammonia from the uncracked and liquid ammonia by means of centrifugal and/or gravitational forces,
- a fuel line for feeding the gaseous hydrogen, nitrogen and ammonia to at least one burner of the gas turbine, and
- a recirculation line connecting the gas-liquid-separator with the feeding line for the transportation of the uncracked, liquid ammonia to the pressurized ammonia.

[0007] Advantages relating to the described method may as well pertain to the system and vice versa.

[0008] The method overcomes the drawbacks of the known prior art by suggesting an efficient way to keep the reaction rate of the cracking process high by continuously suppling heat for from the exhaust gas of the gas turbine. To achieve this, the ammonia is not pre-heated, but the heating step is performed in the ammonia cracking device. In this case, proximity is needed between the gas turbine and the ammonia cracking device, i.e., both are part of one system for generating power using a gas turbine. In particular, the case is excluded, in which the fuel is produced at a different site than the gas turbine, and transported to the gas turbine, which is for instance offshore.

[0009] Another essential difference between the present method and the prior art is that the ammonia is only partially cracked, so that a mixture containing hydrogen, nitrogen and non-cracked ammonia is leaving the ammonia cracking device and fed to the burners of the gas turbine.

[0010] Moreover, the mixture containing hydrogen, nitrogen and non-cracked ammonia is cooled down to ambient temperature, so that the ammonia condenses, but all hydrogen and nitrogen remain fully gaseous. Ammonia content in the gas phase will be determined by the vapor pressure of the ammonia, which depends on the mixture's temperature. This gives the opportunity to con-

trol and know the composition of mixture. At typical gas turbine operating conditions, the ammonia content can be about 30-40%, which gives the resulting fuel mixture a laminar flame speed comparable to the one of natural gas.

[0011] The uncracked, liquified ammonia is eventually recirculated to the incoming ammonia stream. The advantage of this process step is, that the ammonia coming from the gas-liquid-separator is still at high pressure. The proposed system will maximize the utilization of the catalyst, as it allows for high ammonia concentration through the entire catalyst.

[0012] By cracking ammonia to a hydrogen-nitrogen mixture prior to injection into the burner, a fuel is obtained which has a suitable flame speed, as well as fuel bound nitrogen is lowered. A further advantage is also the elevated heating value of the fuel.

[0013] In a preferred embodiment, the ammonia is pressurized from a lower pressure to a higher pressure which is in the range between 15 bar and 50 bar, depending on the type and size of the turbine. This is done by a pump, integrated in the feeding line, which pumps up ammonia to 15-50 bar. Alternatively, the same pressure can be achieved by heating the ammonia storage container.

[0014] In another preferred embodiment, by means of the exhaust gas of the gas turbine, in the ammonia cracking devices the ammonia is heated up from a lower temperature to a higher temperature, which is in the range between 400 °C and 1000 °C. In this case the ammonia cracking device works also as heat exchanger and the heat needed for the endothermic cracking reaction is provided by the gas turbine exhaust gas. The exhaust gas of the gas turbine has a temperature of 450 °C to 650 °C, but depending on the type of turbine and operating conditions this temperature might be higher. In any case the exhaust gas temperature is high enough to heat up the ammonia to the required temperature level so that the cracking process takes place.

[0015] Preferably, the ammonia cracking device is a catalytic ammonia-ammonia cracking device containing a catalyst. Alternative embodiments are also possible, e.g. The ammonia cracking device is preferably a reforming reactor.

[0016] A solid catalyst is preferably employed in the ammonia cracking device in order to ensure an efficient cracking process. In this case the ammonia cracking device contains a solid catalyst selected from nickel catalysts, iron catalysts, manganese catalysts, platinum catalysts, palladium catalysts, lanthanum catalysts, molybdenum catalysts, ruthenium catalysts, cobalt catalysts, lithium catalysts, and zirconium catalysts, or mixtures thereof.

[0017] One embodiment of the invention is now described, by way of example only, with reference to the accompanying drawing. The only figure shows a system 2 for producing a fuel to be burned in a gas turbine 4. Liquid ammonia is fed to the system 2 through a feeding line 6, in which a pump 8 is integrated. The ammonia is pressurized from a lower pressure p_1 which is e.g. 8 bar to higher pressure p_2 at a level between 15 bar and 50 bar, e.g. p_2=50 bar. In the feeding line 6 the ammonia has a lower temperature of T_1 which is 15°C. Alternatively, the pump 8 is omitted, and the ammonia storage is heated to achieve pressure p_2.

[0018] The pressurized ammonia is then fed into an ammonia cracking device 10, which is also functioning as heat exchanger. Exhaust gas heat from the gas turbine 4 is also transferred to the ammonia cracking device 10 by means of a heat line 12, so that in the ammonia cracking device 10 the ammonia is heated up to a higher temperature T_2, in particular to a range between to 400 °C and 1000 °C. For example, T_2=500°C.

[0019] A suitable solid catalyst material is present inside the ammonia cracking device 10. At the typical gas turbine exhaust temperatures, a substantial fraction (but not all) of the ammonia is cracked to hydrogen and nitrogen. The catalyst speeds up this process.

[0020] After leaving the ammonia cracking device 10, the mixture of ammonia, hydrogen and nitrogen is cooled down to ambient temperature, e.g. down to T_1=15°C, in the cooler 14. This temperature can be different from the temperature in the feeding line 6 though. As the pressure remains high at p_2, e.g. 50 bar, part of the ammonia in the mixture will condensate, while hydrogen and nitrogen remain fully gaseous. The partial pressure from gas phase ammonia depends on the temperature T_1 of the mixture. At T_1=15 °C, ammonia vapor pressure is about 7 bar, while the remaining pressure is exerted by the cracked products.

[0021] Next the gaseous cracking products are separated from the uncracked ammonia by means of centrifugal and/or gravitational forces in a gas-liquid-separator 16. The uncracked liquid ammonia is recirculated to the incoming ammonia stream via a recirculation line 18, while the gaseous mixture (hydrogen, nitrogen and ammonia) is fed to the burners 22 of the gas turbine 4 along a fuel line 20. The fuel mixture fed to the burners 22 has a higher heating value than the incoming ammonia, this energy comes from the exhaust heat. It has also a significantly higher reactivity owing to the presence of hydrogen.

Claims

1. Method for producing a fuel for driving a gas turbine (4), including the steps of:

   - pressurizing liquid ammonia,
   - the pressurized ammonia is fed by a feeding line (6) into an ammonia cracking device (10) and partially cracked using exhaust gas heat from the gas turbine (4),
   - a mixture of hydrogen, nitrogen and ammonia is fed out of the ammonia cracking device (10)

to a cooling unit and cooled down to ambient temperature,
- in a gas-liquid-separator (16), the gaseous mixture of hydrogen, nitrogen and ammonia is separated from the liquid ammonia by means of centrifugal and/or gravitational forces,
- the gaseous mixture of hydrogen, nitrogen and ammonia is fed to at least one burner (22) of the gas turbine (4),
- the uncracked, liquid ammonia from the gas-liquid-separator (16) is mixed with the pressurized ammonia in the feeding line (6).

2. Method according to claim 1, wherein the ammonia is pressurized from a lower pressure (p_1) to a higher pressure (p_2) which is in the range between 15 bar and 50 bar.

3. Method according to any of the preceding claims, wherein in the ammonia cracking devices the ammonia is heated up from a lower temperature (T_1) to a higher temperature (T_2) which is in the range between 400 °C and 1000 °C by means of the exhaust gas of the gas turbine (4).

4. Method according to any of the preceding claims, wherein the ammonia cracking device (10) is a catalytic ammonia cracking device (10) containing a catalyst.

5. Method according to claim 4, wherein the ammonia cracking device (10) contains a solid catalyst selected from nickel catalysts, iron catalysts, manganese catalysts, platinum catalysts, palladium catalysts, lanthanum catalysts, molybdenum catalysts, ruthenium catalysts, cobalt catalysts, lithium catalysts, and zirconium catalysts, or mixtures thereof.

6. A system (2) for producing a fuel for driving a gas turbine (4), comprising:

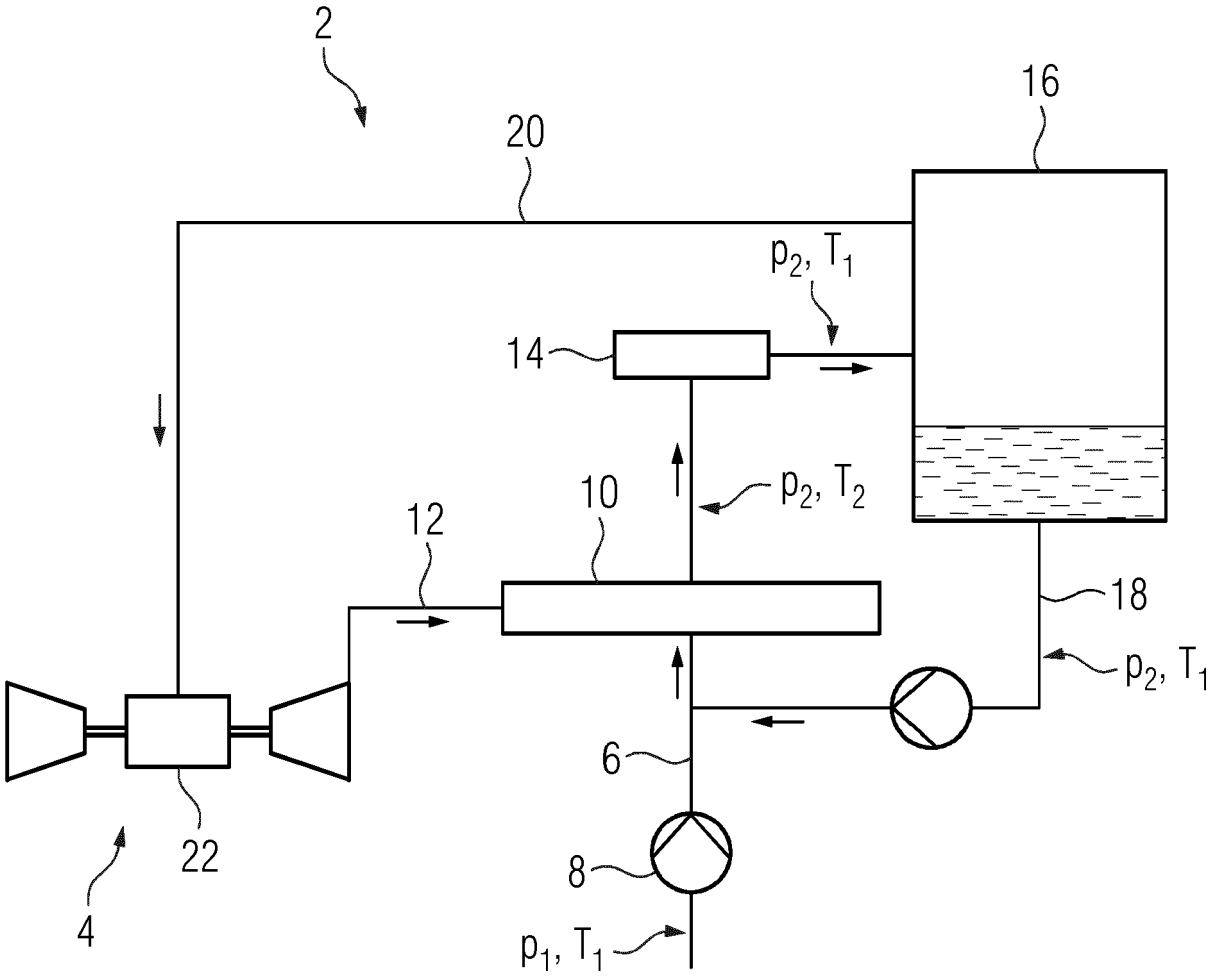
- a feeding line (6) for liquid ammonia in which a pump (8) is integrated,
- an ammonia cracking device (10) arranged on the feeding line (6) for the production of a mixture of hydrogen, nitrogen and ammonia and an exhaust gas line connecting an exit of the gas turbine (4) with the ammonia cracking device,
- a cooling unit for cooling the mixture of hydrogen, nitrogen and ammonia down to ambient temperature,
- a gas-liquid-separator (16) for the separation of the gaseous hydrogen, nitrogen and ammonia from the uncracked and liquid ammonia by means of centrifugal and/or gravitational forces,
- a fuel line (20) for feeding the gaseous hydrogen, nitrogen and ammonia to at least one burner (22) of the gas turbine (4), and
- a recirculation line (18) connecting the gas-liquid-separator (16) with the feeding line (6) for the transportation of the uncracked, liquid ammonia to the pressurized ammonia.

7. System (2) according to claim 6, wherein the pump (8) is configured to the ammonia is pressurized from a lower pressure (p_1) to a higher pressure (p_2) which is in the range between 15 bar and 50 bar.

8. System (2) according to claim 6 or 7, wherein the ammonia cracking devices is configured for heating up the ammonia from a lower temperature (T_1) to a higher temperature (T_2) which is the range between 400 °C and 1000 °C by means of the exhaust gas of the gas turbine (4).

9. System (2) according to any of the claims 6 to 8, wherein the ammonia cracking device (10) is a catalytic ammonia cracking device (10) containing a catalyst.

10. System (2) according to claim 9, wherein the ammonia cracking device (10) contains a solid catalyst selected from nickel catalysts, iron catalysts, manganese catalysts, platinum catalysts, palladium catalysts, lanthanum catalysts, molybdenum catalysts, ruthenium catalysts, cobalt catalysts, lithium catalysts, and zirconium catalysts, or mixtures thereof.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EUROPEAN SEARCH REPORT

Application Number
EP 21 19 7699

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	WO 2017/160154 A1 (STATOIL PETROLEUM AS [NO]) 21 September 2017 (2017-09-21) * abstract; figures 1, 2 * * page 1, lines 1-5 * * page 4, last paragraph - page 5, line 2 * * page 6, lines 8-11, 22-28 * * page 7, lines 7-12 * * page 14, lines 19-29 *	1-10	INV. F01K23/06
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 February 2022	Varelas, Dimitrios

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 19 7699

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REFERENCES CITED IN THE DESCRIPTION

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