

Description**TITLE**

Gas turbine arrangement with ammonia cracker and power plant with such and method to operate a gas turbine arrangement

5 TECHNICAL FIELD

[0001] The invention is about a gas turbine arrangement including an ammonia cracker. The gas turbine comprises as usual a compressor, a combustion section, and an expansion turbine. The ammonia cracker is used to crack the ammonia into a mixture of hydrogen and nitrogen, wherein the hydrogen could be
10 combusted in the gas turbine combustion section.

BACKGROUND

[0002] Conventionally, a natural gas is used as fuel in most gas turbines. To reduce the amount of carbon dioxide it is preferred to use hydrogen as fuel for the gas turbine. The supply and storage of hydrogen is expensive and raises safety
15 concerns. Therefore, ammonia is a preferred medium to store and transport hydrogen from a place of production to a power plant.

[0003] The direct combustion of ammonia as fuel in a gas turbine is not possible due to the release of an unallowable amount of nitrogen oxides (NO_x). Furthermore, the direct combustion of ammonia is difficult due to its ignition inertia.
20 Therefore, it is required to crack at least part of the ammonia into hydrogen and nitrogen before its combustion in the combustion chamber of the gas turbine.

[0004] For cracking of the ammonia, a high temperature is required. Here, very different technologies are used to achieve the required heat within an ammonia cracker.

25 [0005] In general, it is preferred to operate the power plant including the cracking of ammonia and the operation of the gas turbine as efficiently as possible, with minimum waste of energy. Next, it is preferred that no external heat sources or energy sources are required for the cracking of ammonia.

[0006] Exemplary solutions to enable the combustion of ammonia are presented in EP3314166B1, EP3377745B1 and EP3417205B1. In all cases a share of the ammonia is supplied to an ammonia cracker and the resulting hydrogen and nitrogen are further supplied to the combustor of the gas turbine. Advantageously
5 the heat of the exhaust gas from the gas turbine is used to heat the ammonia cracker.

[0007] If the exhaust gas of the gas turbine should be intentionally used within a steam generator to generate steam for a further steam turbine, only a reduced temperature is available within the steam generator, as a relevant share of the
10 heat is already used for the ammonia cracker.

DESCRIPTION OF THE INVENTION

[0008] The task for the current invention is the development of an alternative solution for the ammonia cracker installed in a combustion arrangement without a relevant reduction of the exhaust gas temperature (so a use of the exhaust gas in
15 a steam generator is enabled). Also, the usage of external heat or an external energy source should be avoided – as far as possible.

[0009] The task is solved by an inventive combustion arrangement according to claim 1. An inventive gas turbine with a respective combustion arrangement is determined in claim 10. Inventive methods to operate a combustion arrangement
20 and a gas turbine are given with in claim 9 and claim 12. Advantageous embodiments are subject of the subclaims.

[0010] A generic combustion arrangement is expediently used with a gas turbine. Independently thereof, the embodiment may be used for other facilities in which a combustion of ammonia is provided. In any case, the combustion arrangement
25 comprises at least one burner and one combustion chamber. According to the intended use of the combustion device, the burner is supplied with combustion air and fuel. Both are fed through the burner into the combustion chamber and can be burned accordingly in the combustion chamber.

[0011] Furthermore, it may be provided that a plurality of burners is arranged at the combustion chamber. In this case, the implementation according to the invention may apply to one or more of the existing burners. Preferably, in this case, the solution according to the invention is considering all existing burners.

- 5 [0012] An ammonia cracker is required for the cracking of the ammonia into hydrogen and nitrogen. Therefore, the ammonia cracker has a reaction channel starting at an ammonia inlet and ending at a fuel outlet. In operation of the combustion arrangement gaseous ammonia needs to be supplied to the ammonia cracker. Intentionally, it is required to connect the ammonia inlet of the reaction
10 channel with a source of ammonia.

- [0013] To enable the cracking process, it is required to operate the ammonia cracker with the required temperature. Therefore, the generic ammonia cracker has heating means. In operation of the combustion arrangement the heating means introduces heat into the ammonia passing the reaction channel. This leads
15 to a splitting of the ammonia into hydrogen and nitrogen with a share of remaining ammonia.

[0014] To enable the combustion of the hydrogen generated within the ammonia cracker, it is required that the fuel outlet of the reaction channel is fluidly connected with the combustion chamber.

- 20 [0015] Depending on the arrangement of the ammonia cracker, it is possible to make use of a fuel piping between the fuel outlet of the reaction channel and the burner. If several burners are given and the ammonia cracker is arranged in flow direction of the ammonia before the burner, it is obvious, that the fuel piping from the fuel outlet is preferably branching to all installed burners.

- 25 [0016] To achieve a preferred efficiency and to reduce the installation effort it is inventively required, that a transfer section forms a section of the combustion chamber. The combustion within the combustion chamber leads to a heating of the surrounding walls of the combustion chamber and consequently to a heating of the transfer section as part of the surround walls of the combustion chamber. Next,

a further heat transfer from the transfer section into the reaction channel has to be enabled.

[0017] To enable an advantageous heat transfer from the transfer section into the reaction channel the ammonia cracker comprises further a heat conductor. The transfer section is thereby either part of the heat conductor or attached directly to the heat conductor to enable the beneficial heat transfer from the combustion chamber into the reaction channel. Therefore, the reaction channel passes the heat conductor.

[0018] Consequently, the heating means comprises the heat conductor and the transfer sections.

[0019] The beneficial usage of heat produced by the combustion process within the combustion chamber for the splitting of ammonia directly at the combustion chamber the effort for the installation of piping arrangements as if an ammonia cracker is placed for example at the exhaust path could be avoided. Instead, the cracked hydrogen and nitrogen could be guided to the combustion chamber by a short route.

[0020] It is in particular advantageous, if the ammonia cracker is installed directly adjacent to the combustion chamber, so that a short distance between the combustion chamber and the reaction channel is enabled.

[0021] Preferably, the arrangement achieves a heating of the ammonia during the combustion process to a temperature above 600 °C. A temperature of above 700 °C is particularly advantageous.

[0022] If required to achieve the required temperature for the cracking of the ammonia, it is advantageously possible to add an ammonia burner as further heating means. Intentionally the ammonia burner is enabled to combust a share of the ammonia supplied to the ammonia cracker within the ammonia cracker with combustion air.

[0023] Instead of using an external energy source for the heating within the ammonia cracker advantageously the ammonia is directly used as fuel for the

ammonia burner as heating means. The combustion of ammonia, a further increase of the efficiency of the combustion arrangement could be achieved.

[0024] The combustion of ammonia within the ammonia cracker could be enabled preferably with two different embodiments. A first embodiment requires a combustion air nozzle arranged at the reaction channel. The injection of combustion air into the flow of ammonia enables the combustion of a share of the ammonia directly inside the reaction channel. This leads to a in particular advantageous splitting of the remaining ammonia – the larger share of supplied ammonia, which is not combusted by the ammonia burner – into hydrogen and nitrogen. Obviously, a mixture of hydrogen and nitrogen and further of possible remaining ammonia and steam is leaving the reaction channel, to be guided into the combustion chamber.

[0025] In a second embodiment the ammonia cracker requires a heating channel additionally to the reaction channel. Here, the ammonia burner is arranged at the input side of the heating channel and the output side of the heating channel is fluidly connected with the combustion chamber. In operation of the combustion arrangement combustion air and ammonia needs to be supplied to the ammonia burner.

[0026] It is possible to make use of one common piping to the ammonia input of the reaction channel and to the ammonia burner. It is also possible to supply the reaction channel separately from the ammonia burner with ammonia by use of separated piping.

[0027] To enable a control of the introduction of heat into the reaction channel by combustion of ammonia at the ammonia burner it is possible to control the flow of ammonia to the ammonia burner – if a dedicated piping to the ammonia burner is given. Next, it is possible to control the flow of combustion air to the ammonia burner.

[0028] To enable heating of the ammonia in the ammonia cracker to the required temperature for cracking the ammonia, it is advantageous if the ammonia supplied to the ammonia cracker has already at an increased temperature. It could be

expected that the ammonia supplied from a source of ammonia has a low temperature compared to the required temperature within the ammonia cracker. The mixture of hydrogen and nitrogen leaving the ammonia cracker on the other hand has a high temperature due to the heating within the ammonia cracker
5 required for the cracking process.

[0029] Here, it is advantageous to reuse the heat in the mixture for the heating of the ammonia supplied to the ammonia cracker. Therefore, the combustion arrangement advantageously comprises a fuel heat exchanger. The fuel heat exchanger should have a first ammonia passage and a fuel passage.

10 [0030] The fuel passage of the fuel heat exchanger needs to be fluidly connected at an input side with the fuel output at the ammonia cracker. The first ammonia passage of fuel heat exchanger needs to be fluidly connected at an output side with the ammonia input of the ammonia cracker.

15 [0031] The source of ammonia needs to be fluidly connected intentionally with the input side of the first ammonia passage of fuel heat exchanger, wherein the output side of the fuel passage of fuel heat exchanger needs to be fluidly connected with the at least one burner. Obviously, in this preferred embodiment the flow of fuel (first as ammonia and second as mixture of hydrogen and nitrogen) crosses the fuel heat exchanger twice.

20 [0032] The usage of a fuel heat exchanger additionally to the ammonia cracker enables an efficient reuse of the heat introduced into the ammonia cracker for the preheating of the ammonia.

25 [0033] A further advantageous possibility to enable heating of the ammonia in the ammonia cracker to the required temperature for cracking the ammonia, by supplying the ammonia to the ammonia cracker with an increased temperature is given if the advantage combustion arrangement comprises a fuel preheater.

[0034] It is required that the fuel preheater has a second ammonia passage and an air passage. An input of the second ammonia passage needs to be fluidly connected for the operation of the combustion arrangement with a source of

ammonia. If a fuel heat exchanger is installed, it is required to fluidly connect an output of the second ammonia passage with the input of the first ammonia passage. If the fuel heat exchanger is not foreseen, then it is required to fluidly connect the output of the second ammonia passage with the ammonia input of the
5 reaction channel.

[0035] An output of the air channel has to be fluidly connected to the combustion chamber. For the operation of the combustion arrangement, it is intentionally required to fluidly connect an input of the air channel with a source of combustion air.

10 [0036] The combustion air is usually supplied to the combustion arrangement at an increased pressure. If the combustion air has further an increased temperature in this process, the heat from the combustion air can be used to preheat the ammonia.

[0037] The inventive combustion arrangement and its preferred embodiments
15 enable the building of an inventive gas turbine. A generic gas turbine comprises a compressor and at least one combustor and an expansion turbine. Inventively as combustor a combustion arrangement according the preceding description is used.

[0038] The compressor has a compressor inlet, several compressor stages and a
20 compressor outlet. In operation of the gas turbine, combustion air – which is in usual filtered ambient air – flows into the compressor inlet, is compressed and supplied from the compressor outlet. As result the compressed combustion air at the compressor outlet has an increased temperature due to the compression process.

25 [0039] Different kind of combustion arrangements could be used for the inventive solution. It is possible to use an annular combustion chamber with a number of burners distributed around the gas turbine centre axis. Alternative, a silo combustion system or a number of can-combustors distributed around the gas turbine centre axis each having usually one burner could be used. In any case the
30 compressed combustion air is supplied at least in portion from the compressor

outlet to the combustion arrangement. Additionally, a fuel needs to be supplied to the at least one burner of the combustion arrangement in operation of the gas turbine.

[0040] The expansion turbine is arranged downstream of the combustion arrangement, driven in operation of the gas turbine by the flow of hot exhaust gas. After expansion of the hot exhaust gas in the expansion turbine the exhaust gas leaves the expansion turbine with a reduced temperature at the output end of the gas turbine.

[0041] If the ammonia cracker comprises the preferred ammonia burner, it is advantageous to fluidly connect the ammonia burner with the compressor exit, so that a share of the compressed combustion air could be supplied to the ammonia burner to enable the combustion of ammonia within the ammonia cracker.

[0042] If the combustion arrangement comprises an ammonia preheater, it is advantageous to fluidly connect the inlet of the air passage of the ammonia preheater with the compressor exit, so that so that a share of the compressed combustion air could be supplied to the ammonia preheater to transfer the heat within the compressed combustion air into the ammonia.

[0043] By using the heat from the combustion chamber through the transfer section preferably in addition with the combustion of ammonia within the ammonia cracker preferably in addition with the preheating of the ammonia by use of the heat of the compressed combustion air preferably in addition with the reuse of the heat of the cracked ammonia to further preheat the ammonia, the efficiency of the gas turbine could be increased and thereby the hot exhaust gas leaving the gas turbine could still be used for operation of a steam generator.

[0044] It is possible to provide the ammonia by the source of ammonia in gaseous form.

[0045] If the source of ammonia provides the ammonia in liquid form, it is preferred to use additionally an ammonia vaporizer. The ammonia vaporizer should comprise a fluid passage and a vaporizing passage, wherein the vaporizing

passage of the ammonia vaporizer is fluidly connected at an input side with the source of fuel and at the output side of the ammonia vaporizer with input side of the first ammonia passage of the preferred fuel heat exchanger or – if given – with the input side of the second ammonia passage of the preferred ammonia
5 preheater.

BRIEF DESCRIPTION OF DRAWINGS

- [0046] **FIG 1** shows schematically an exemplary embodiment of an inventive combustion arrangement 01 having a combustion chamber, burners and an ammonia cracker.
- 10 [0047] **FIG 2** shows schematically the arrangement of a combustion arrangement 01 at a gas turbine 05 to enable the combustion ammonia respectively hydrogen.

DESCRIPTION OF EMBODIMENTS

- [0048] In **Figure 1** an inventive combustion arrangement 01 with an exemplary arrangement of an ammonia cracker 11 is shown. The combustion arrangement
15 01 comprises a combustion chamber 03 and illustrative two burner 02. In operation of the combustion arrangement, the burners 02 are supplied with fuel, i.e., a mixture comprising hydrogen, and combustion air. The fuel and the combustion air are introduced into the combustion chamber 03 and combusted.
- [0049] Relevant for the implementation is the arrangement of the ammonia
20 cracker 11 adjacent to the combustion chamber 03. Thereby a transfer section 13 limits in partial the surrounding walls of the combustion chamber 03. Due to this arrangement heat, generated within the combustion chamber 03 during the combustion of hydrogen, is transferred partially into the transfer section 13.
- [0050] The ammonia cracker 11 comprises a reaction channel 12 extending
25 through the ammonia cracker 11 from an ammonia input to a fuel output. Next, the ammonia cracker 11 comprises heating means, wherein the transfer section 13 limiting in portion the combustion chamber 03 is part of this heating means.

[0051] Intentionally heat could be transferred from the transfer section 13 into the reaction channel 12. Therefore, the ammonia cracker 11 further comprises in this embodiment a heat conductor 14, wherein the transfer section 13 is part of the heat conductor 14 at the boundary between the ammonia cracker 11 and the combustion chamber 03.

[0052] To introduce additional heat into the reaction channel 12 the ammonia cracker 11 further comprises an ammonia burner 15. In this exemplary embodiment the ammonia burner 15 is arranged at the ammonia input of the reaction channel 12. In operation of the combustion arrangement, the ammonia burner is supplied with ammonia and additionally with combustion air. This leads to a partially combustion of the ammonia and an increase of the temperature.

[0053] The exemplary solution further comprises a fuel heat exchanger 21 having a first ammonia passage 22 and a fuel passage 23. Ammonia is supplied to the input side of the first ammonia passage 22 and after heating guided from an output side of the first ammonia passage 22 to the ammonia input of the reaction channel 12 of the ammonia cracker 11.

[0054] The cracked fuel as mixture of hydrogen, nitrogen and a remaining share of ammonia and the gases generated by the combustion of ammonia, in particular steam, are guided from the fuel output of the reaction channel 12 to the input side of the fuel passage 23 of the fuel heat exchanger 21. The fuel mixture is further guided from the output side of the fuel passage 23 to the burners to enable the combustion of hydrogen inside the combustion chamber.

[0055] Additionally, an ammonia preheater 24 is arranged in flow direction before the fuel heat exchanger 21. Intentionally combustion air is guided through an air passage in the ammonia preheater 24 to heat up ammonia passing through a second ammonia passage within the ammonia preheater 24. Therefore, ammonia is supplied to the input side of the second ammonia passage and is further guided with an increased temperature from the output side of the second ammonia passage to the input side of the first ammonia passage 22.

[0056] To enable the supply of gaseous ammonia an ammonia vaporizer 25 is shown in flow direction before the ammonia preheater 24, wherein liquid ammonia could be supplied from a source of ammonia 04.

[0057] In **Figure 2** an exemplary embodiment for a gas turbine 05 having a combustion arrangement 01 according to figure 1 is shown. The gas turbine 05 comprises a compressor, the combustion arrangement 01 – shown simplified just as box, see fig. 1 – and an expansion turbine 07.

[0058] In operation of the gas turbine 05 compressed air with an increased temperature is guided from the compressor exit to the input side of the air passage within the ammonia preheater 24. The combustion air and further preheated ammonia is further guided from the ammonia preheater 24 to the combustion arrangement 01.

[0059] After the combustion of a share of ammonia and the cracked hydrogen within the combustion arrangement 01 a flue gas is guided through the expansion turbine 07 to drive a rotor in regular to drive a generator.

[0060] It has to be noted, that the shown fuel heat exchanger 21 and also the ammonia preheater 24 could be arranged separate from the combustion arrangement 01 with the required piping in-between.

[0061] It is also possible to arrange the fuel heat exchanger 21 also adjacent respectively close to the ammonia cracker 11 to reduce the piping effort and make best use of the heat inside the system.

[0062] Next, it is also possible to arrange the ammonia preheater 24 adjacent or close to the ammonia cracker 11 or combustion chamber 03. Thereby, it is also possible to guide at least a share of the combustion air first along the combustion chamber for cooling purposes and then introduce the further heated combustion air into the ammonia preheater 24.

Claims

1. Combustion arrangement (01), in particular of a gas turbine, comprising at least one burner (02) and a combustion chamber (03), wherein intentionally combustion air and fuel is supplied to the burner (02) and burned in the
5 combustion chamber (03); further comprising an ammonia cracker (11) having heating means and a reaction channel (12); wherein an outlet of the reaction channel (12) is fluidly connected to the burner (02), wherein intentionally ammonia is supplied to an inlet of the reaction channel (12) from a source of ammonia;
10 characterized in that the heating means comprises a heat conductor (14) and a transfer section (13), wherein the reaction channel (12) crosses the heat conductor (14) and the transfer section (13) forms a section of the combustion chamber (03) and enables a heat transfer from the combustion chamber (03) to the reaction
15 channel (12).
2. Combustion arrangement (01) according to claim 1, wherein the ammonia cracker is arranged next to the combustion chamber.
3. Combustion arrangement (01) according to claim 1 or 2, wherein the heating means further comprises an ammonia burner (15),
20 wherein intentionally combustion air and ammonia is be supplied to the ammonia burner (15) and burned inside the ammonia cracker (11).
4. Combustion arrangement (01) according to claim 3, wherein the ammonia burner (15) comprises a combustion air nozzle, enabling the combustion of ammonia within the reaction channel (12).
- 25 5. Combustion arrangement (01) according to claim 3, wherein the ammonia cracker (11) comprises a heating channel separated from the reaction channel with the ammonia burner arranged at its input side and connected with its output side to the combustion chamber (03).

6. Combustion arrangement (01) according to one of the claims 1 to 5,
further comprising a fuel heat exchanger (21) having a fuel passage (23) and
a first ammonia passage (22), wherein an output of the first ammonia
passage (22) is fluidly connected with the ammonia cracker (11) and
5 intentionally ammonia is supplied to an input of the first ammonia passage
(22) and an input of the fuel passage (23) is fluidly connected to the output of
the reaction channel (12) and an output of the fuel passage (23) is fluidly
connected to the burner (02).
7. Combustion arrangement (01) according to claim 6,
10 further comprising an ammonia preheater (24) having a second ammonia
passage and an air passage, wherein an output of the second ammonia
passage is fluidly connected with the input of the first ammonia passage (22)
or with the ammonia input of the reaction channel (12) and intentionally
ammonia is supplied to an input of the second ammonia passage and an
15 output of the air passage is fluidly connected to the burner (02) and
intentionally combustion air is supplied to an input of the air passage .
8. Method for operate a combustion arrangement (01) according to one of the
foregoing claims,
wherein ammonia is supplied by an ammonia source and passed through the
20 reaction channel (12) and is at least partially split therein into hydrogen and
nitrogen and supplied into the burner (02) and burned inside the combustion
chamber (03),
wherein thermal energy generated by the combustion is transferred partially
from the transfer section (13) to the heat conductor (14) and further to the
25 ammonia flowing through the reaction channel (12).
9. Gas turbine (05) comprising
a compressor (06) and a combustion arrangement (01) according on of the
foregoing claims and an expansion turbine (07).
10. Gas turbine (05) according to claim 9,
30 wherein the exit of the compressor (06) is fluidly connected to the ammonia
burner (15).

11. Gas turbine (05) according to claim 9 or 10,
wherein the exit of the compressor (06) is fluidly connected to the air
passage of the ammonia preheater (24).
12. Method to operate a gas turbine (05) having a gas turbine (05) according one
5 of the forgoing claims, wherein
- combustion air is compressed and heated by the compressor (06) and
guided through the air passage;
 - a share of the compressed air is supplied to the burner (02) and another
share is supplied to the ammonia burner (15);
 - 10 - additional heat is introduced in the ammonia cracker (11) by the combustion
of ammonia;
 - ammonia is supplied to the ammonia inlet of the reaction passage (12) and
heated up and cracked into hydrogen and nitrogen and guided as fuel gas
from the outlet of the reaction passage (12) to the burner (02);
 - 15 - hydrogen is combusted within the combustion chamber (03); and
 - resulting flue gases are guided from the combustion chamber (03) through
the expansion turbine (07).
13. Method according claim 12,
wherein compressed and heated combustion air is at least partially guided
20 from the exit of the compressor (06) to the air passage.