

TITLE

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

Description

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 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 heat is already used for the ammonia cracker.

SUMMARY OF INVENTION

[0008] The task for the current invention is the development of an alternative solution for the ammonia cracker installed in a gas turbine arrangement without a relevant reduction of the exhaust gas temperature (so a use of the exhaust gas in 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 gas turbine arrangement according to claim 1. An inventive method to operate a gas turbine arrangement with an ammonia cracker is defined in claim 6. Advantageous embodiments are subject of the subclaims.

[0010] The gas turbine arrangement comprises a compressor, and a combustor and an expansion turbine, wherein in operation of the gas turbine combustion air is compressed in the compressor and at least a part of the combustion air is supplied from an outlet of the compressor to the combustor and an exhaust gas is supplied in operation of the gas turbine from the combustor to the expansion turbine.

[0011] An ammonia cracker having a heater, and an ammonia channel and a cracker reaction channel is required to enable the combustion of ammonia. The

arrangement further comprises a fuel heat exchanger having an exchanger fuel passage and an exchanger ammonia passage, The inlet of the exchanger ammonia passage has to be connected to a source of ammonia, wherein an outlet of the exchanger ammonia passage is connected with an inlet of the cracker reaction channel.

[0012] An improved efficiency is enabled, if a hot air piping connects the compressor outlet with an inlet of the cracker air channel and a cold air piping connects the outlet of the cracker air channel with the combustor. Further, a first fuel piping connects an outlet of the cracker reaction channel with an inlet of the exchanger fuel passage and a second fuel piping connects the outlet of the exchanger fuel passage with the combustor (03).

DESCRIPTION OF THE INVENTION

[0013] A generic gas turbine arrangement comprises a gas turbine and an ammonia cracker. The gas turbine comprises a compressor and at least one combustor and an expansion turbine.

[0014] The compressor has a compressor inlet, several compressor stages and a 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.

[0015] 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 (regular each has one burner and one combustion chamber) distributed around the gas turbine centre axis could be used. In any case, the compressed combustion air is supplied at least in portion from the compressor outlet (directly or indirectly) to the at least one combustor. Additionally, a fuel needs to be supplied to the at least one burner of the at least one combustor in operation of the gas turbine.

[0016] The expansion turbine is arranged downstream of the at least one combustor, 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.

[0017] The generic ammonia cracker is required for the cracking of the ammonia into hydrogen and nitrogen. Therefore, the ammonia cracker has a cracker reaction channel crossing the ammonia cracker from an inlet to an outlet.

[0018] 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 fuel gas comprising hydrogen and nitrogen leaving the ammonia cracker on the other hand has a high temperature due to the heating within the ammonia cracker required for the cracking process. Here, it is advantageous to reuse the heat in the fuel gas for the heating of the ammonia supplied to the ammonia cracker.

[0019] The gas turbine arrangement inventively comprises a fuel heat exchanger. The fuel heat exchanger should have an exchanger ammonia passage and an exchanger fuel passage. In use of the gas turbine arrangement, an inlet of the exchanger ammonia passage needs to be connected with a source of ammonia. An outlet of the exchanger ammonia passage of fuel heat exchanger needs to be connected with the inlet of the cracker reaction channel of the ammonia cracker.

[0020] To enable a transfer of heat, a first fuel piping is required to connect the outlet of the cracker reaction channel with an inlet of the exchanger fuel passage of fuel heat exchanger. Obviously, in this inventive embodiment the flow of fuel (first as ammonia and second as fuel gas comprising hydrogen and nitrogen) crosses the fuel heat exchanger twice.

[0021] Further, a second fuel piping is required connecting an outlet of the fuel passage of fuel heat exchanger with the at least one combustor. If several burners are given, it is obvious, that the second fuel piping is preferably branching to all installed burners.

[0022] To enable the cracking process, it is required to operate the ammonia cracker with the required temperature. To achieve a preferred efficiency and to avoid the usage of heat from the exhaust gas leaving the gas turbine, it is inventively required, that at least a portion of the compressed air is used in the ammonia cracker to introduce heat for the cracking process. In operation of the gas turbine arrangement the temperature of the compressed air at the compressor outlet is usually lower than the exhaust gas downstream of the combustor. Nevertheless, the temperature is much higher than the usual ambient temperature.

[0023] To enable the usage of the heat of the compressed air, the ammonia cracker comprises further a cracker air channel to enable the flow of compressed combustion air through the ammonia cracker from an inlet to an outlet of the cracker air channel.

[0024] The gas turbine arrangement comprises a hot air piping connecting the compressor outlet of the compressor with the inlet of the cracker air channel of the ammonia cracker. Further, a cold air piping is required, which connects the outlet of the cracker air channel with the at least one combustor to enable the flow of combustion air to enable the burning of the fuel in the combustor. In operation of the gas turbine arrangement, the "cold air piping" is still hotter than the ambient air but has a lower temperature than the "hot air piping".

[0025] The generic ammonia cracker comprises a heater to heat the ammonia up to the required temperature to enable the cracking of the ammonia into hydrogen and nitrogen.

[0026] By using the heat of the compressed air with additional heating by the heater, the efficiency of the gas turbine arrangement could be increased and thereby the hot exhaust gas leaving the gas turbine could still be used for operation of a steam generator.

[0027] Instead of using an external energy source for the heater of the ammonia cracker advantageously the cracked hydrogen is used as fuel for the heater. The combustion of hydrogen, which has been cracked in the ammonia cracker, within

the heater, a further increase of the efficiency of the gas turbine arrangement could be achieved.

[0028] It is obvious, that for a starting process initially the hydrogen for the additional heat in the ammonia cracker needs to be supplied externally. But in principle, in regular operation of the gas turbine arrangement, the hydrogen necessary to operate the heater advantageously should be diverted from the stream of hydrogen and nitrogen leaving the ammonia cracker at the fuel outlet.

[0029] In principle it is possible to install a separate combustion system within the ammonia cracker to burn the hydrogen. But it is advantageous to burn the hydrogen directly within the air channel within the ammonia cracker. This reduces the installation effort and increases the efficiency.

[0030] To supply the heater of the ammonia cracker with a share of the cracked ammonia, it is possible to connect the heater to the first fuel piping between the outlet of the cracker reaction channel and the inlet of the exchanger ammonia passage. Alternatively, the heater could be connected to the second fuel piping between the outlet of the exchanger ammonia passage and the combustor.

[0031] It is possible to provide the ammonia by the source of ammonia in gaseous form.

[0032] 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 intentionally connected at an input side with the source of fuel and at the output side of the ammonia vaporizer is connected with the inlet of the exchanger ammonia passage.

[0033] In this case, the fluid passage of the ammonia vaporizer needs to be supplied with a heated medium.

[0034] The preferred embodiment of the gas turbine arrangement comprises a steam generator arranged downstream to the expansion turbine. Within the steam

generator a number of heat exchangers are required to transfer the heat of the exhaust gas to the generate the steam.

[0035] In combination with the preferred ammonia vaporizer, it is advantageous to use the heat of the exhaust gas additionally to the generation of steam for the pre-
5 heating of the ammonia. Here two different solutions are proposed.

[0036] In a first embodiment the fluid passage of the ammonia vaporizer is connected with the output side and with the input side of at least one of the heat exchangers installed within the steam generator.

[0037] In a second embodiment a section of the steam generator builds also the
10 ammonia vaporizer, wherein the vaporizing passage is installed as heat exchanger within the steam generator and the passage for the exhaust gas is the fluid passage of the ammonia vaporizer.

[0038] In both cases the heat exchanger connected to the ammonia vaporizer or the ammonia vaporizer as section of the steam generator should be arranged at
15 the downstream end of the steam generator so to enable primary the generation of steam with the heat from the exhaust gas.

DESCRIPTION OF DRAWINGS

[0039] In the figure an exemplary embodiment of an inventive gas turbine arrangement 01 is schematically shown.

20 [0040] The gas turbine arrangement 01 comprises a gas turbine with a compressor 02 and a combustor 03 and an expansion turbine 04. A steam generator 05 is arranged downstream to the expansion turbine 04.

[0041] Within the steam generator 05 a number of heat exchangers (not shown) are installed, wherein at least one heat exchanger is connected with a steam
25 turbine 06.

[0042] The compressed combustion air is usually supplied from the compressor 02 to the combustor 03, wherein the produced exhaust gas is supplied from the combustor 03 to the expansion turbine 04 to drive a gas turbine rotor.

[0043] Here, it is required, that at least a portion of the compressed combustion air is branched off and supplied to an ammonia cracker 11. An cracker air passage enables the flow of compressed air through the ammonia cracker 11. Therefore, an inlet of the cracker air passage is connected with the compressor outlet. An outlet of the cracker air passage is connected with the combustor 03. Consequently, the compressed combustion air flows into the combustor 03 at least in portion after crossing the ammonia cracker 11.

[0044] Within the ammonia cracker 11 a cracker reaction passage and a heater 15 are arranged. A gaseous ammonia is supplied to an inlet of the cracker reaction passage. A mixture of hydrogen and nitrogen is delivered from an outlet of the cracker reaction passage. The heat in the cracker reaction passage enables the cracking of ammonia, which is provided in portion by the compressed air and in portion by the heater 15.

[0045] The inlet of the cracker reaction passage and also the outlet of the cracker reaction passage are connected to a fuel heat exchanger 12. The fuel heat exchanger 12 therefore comprises an exchanger ammonia passage and an exchanger fuel passage.

[0046] Ammonia is supplied to an inlet of the exchanger ammonia passage. By crossing the fuel heat exchanger 12 through the exchanger ammonia passage the ammonia is heated up by use of the heat within the mixture of hydrogen and nitrogen passing through the exchanger fuel passage. This leads to an efficient reuse of the heat, which is required in the ammonia cracker 11.

[0047] An outlet of the exchanger fuel passage of the fuel heat exchanger 12 is connected to the combustor 03, so that the fuel – the mixture of hydrogen and nitrogen – could be used for the combustion process within the gas turbine.

[0048] A share of the produced hydrogen is branched off and supplied to the heater 15 within the ammonia cracker 11 to reach the required temperature for the cracking process. In this embodiment the heater 15 is attached to the second fuel piping between the outlet of the exchanger fuel passage and the combustor 03.

- 5 But, it is alternatively possible to connect the heater to the first fuel passage between the outlet of the cracker reaction channel of the ammonia cracker 11 and the inlet of the exchanger ammonia passage of the heat exchanger 12.

- [0049] To enable the usage of liquid ammonia as source 14 of ammonia, an ammonia vaporizer 13 is installed in-between the source 14 of ammonia and the
10 fuel heat exchanger 12. In the ammonia vaporizer 13 by a heat transfer the ammonia changes its state from liquid to gaseous.

[0050] Therefore, the ammonia vaporizer 13 is connected to a heat exchanger installed within the steam generator 05.

Claims

1. Gas turbine arrangement (01) comprising
 - a gas turbine having a compressor (02) and a combustor (03) and an expansion turbine (04), wherein in operation of the gas turbine combustion
 - 5 air is compressed in the compressor (02) and at least a part of the combustion air is supplied from an outlet of the compressor (02) to the combustor (03) and a exhaust gas is supplied in operation of the gas turbine from the combustor (03) to the expansion turbine (04); and
 - an ammonia cracker (11) heaving a heater (15) and an cracker air channel and a cracker reaction channel; and
 - 10 - a fuel heat exchanger (12) having a exchanger fuel passage and an exchanger ammonia passage;wherein in use of the gas turbine arrangement (01) an inlet of the exchanger ammonia passage is intentionally connected to a source (14) of ammonia and an outlet of the exchanger ammonia passage is connected with an inlet
 - 15 of the cracker reaction channel,
 - wherein a first fuel piping connects an outlet of the cracker channel with an inlet of the exchanger fuel passage and a second fuel piping connects an outlet of the exchanger fuel passage with the combustor (03), and
 - 20 wherein a hot air piping connects the compressor outlet with an inlet of the cracker air channel and a cold air piping connects an outlet of the cracker air channel with the combustor (03) .
2. Gas turbine arrangement (01) according to claim 1,
 - wherein the second fuel piping branches off with a heater piping to the heater
 - 25 (15).
3. Gas turbine arrangement (01) according to claim 2,
 - wherein the heater (15) is enabled to combust hydrogen within the air channel.

4. Gas turbine arrangement (01) according to one of the claims 1 to 3,
further comprising
- a ammonia vaporizer (13) having a vaporizer fluid passage and a vaporizer ammonia passage, wherein an inlet of the the vaporizer ammonia passage is
5 intentionally connected with the source (14) of ammonia and an outlet of the vaporizer ammonia passage is connected with the inlet of the exchanger ammonia passage.
5. Gas turbine arrangement (01) according to claim 4,
further comprising
10 - a steam generator (05), which (05) is arranged downstream of the expansion turbine (04) and has a number of heat exchangers;
wherein the ammonia vaporizer (13) is connected to at least one of the heat exchangers or
wherein the ammonia vaporizer (13) is arranged within the steam generator
15 (05) as one of the heat exchangers.
6. Method to operate a gas turbine arrangement (01)
having a gas turbine arrangement (01) according one of the forgoing claims,
- wherein at least a share of the compressed air is supplied to the ammonia cracker (11);
20 - wherein additional heat is introduced in the ammonia cracker (11) by the heater (15);
- wherein ammonia is supplied form a source (14) of ammonia to the fuel heat exchanger (12) and guided through the exchanger ammonia passage and from the fuel heat exchanger (12) to the ammonia cracker (11);
25 - wherein ammonia is heated up within the cracker reaction channel and thereby cracked into fuel gas comprising hydrogen and nitrogen+;
- wherein the cracked fuel gas is supplied from the ammonia cracker (11) to the fuel heat exchanger (12) and guided through the exchanger fuel passage to transfer heat to the ammonia in the exchanger ammonia passage;
30 - wherein the fuel gas is supplied from the fuel heat exchanger (12) to the combustor (03).

7. Method according claim 6,
wherein a share of the fuel gas is extracted from the second fuel piping and
supplied to the heater (15) and burned within the ammonia cracker (11).