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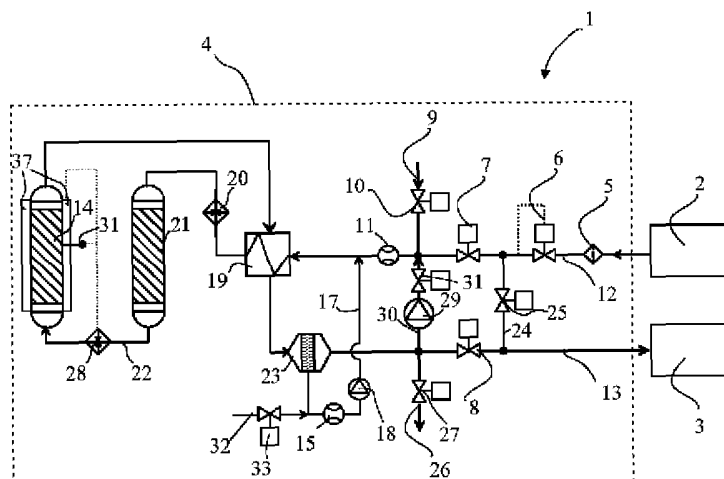
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(54) Title: METHOD OF OPERATING A GAS ENGINE PLANT AND FUEL FEEDING SYSTEM OF A GAS ENGINE



(57) Abstract: Invention relates to a method of operating a gas engine plant (1) comprising a combustion engine (3) adapted to be combust gaseous fuel and a fuel feeding system of the combustion engine with a source of fuel (2), the method being characterised in that heavier hydrocarbons in the fuel are cracked prior to feeding the fuel into the gas engine (3) in a reformer unit (14) provided in a fuel feeding system of the gas engine (3).

Description

METHOD OF OPERATING A GAS ENGINE PLANT AND FUEL FEEDING SYSTEM OF A GAS ENGINE

[0001] Invention relates to method of operating gas engine plant according to preamble of claim 1. Invention also relates to fuel feeding system of a gas engine according to preamble of claim 9.

[0002] Raw natural gas is often the only feasible fuel available to operate power generators and compressor stations in remote locations and on offshore platforms. In many cases, the gas contains unacceptable levels of heavier hydrocarbons. Use of this untreated gas in piston engines and gas turbines causes operating problems. The knock resistance of gaseous fuels is often evaluated by the methane number. In gas engines with high compression ratio and therefore also high thermal efficiency, heavy hydrocarbons constituents in the gaseous fuel will lead to a reduced methane number. In many cases gas engines running directly on the gas fuel available can often not produce as high output as desired in gas operating mode due to too low methane number of the gas mixture. In case that a gas engine is requested to be loaded above the output limited by the methane number, it will start knocking and the output has to be reduced.

[0003] Also in gas turbines the gas to be used must be set and taken into account at designing stage. In case the gas turbine has been designed to be operated with e.g. methane, using of gas containing heavier hydrocarbons is problematic.

[0004] Another problem which relates to prior art particularly in connection with oil drilling rigs, that is it would be advantageous to utilize certain liquid fuels which presently are of no feasible use, like gas condensates. It would be beneficial to be able to operate combustion engines originally designed to run with gas, also with liquid fuels, like gas condensate obtained in oil drilling process. Normally this is not possible without changes in the construction of the engine, which can not be done each time when different fuel should be used.

[0005] It is an object of the invention to provide a method of operating gas engine plant in which the performance of the engine is maintained at proper level even with fuel containing heavier hydrocarbons, and even run a gas engine by making use of liquid fuel. It is also an object of the invention to provide a fuel feeding system of a gas engine which provides high fuel with high methane number for the gas engine in simple and easily controllable manner.

[0006] In connection with this specification the phrase "gas engine" means generally gas operated combustion engine. With wording "heavier hydrocarbons" it is meant hydrocarbons which are heavier than methane, CH₄.

- [0007] The objects of the invention are mainly achieved as disclosed in the appended claims 1 and 9, and as more closely explained in other claims.
- [0008] According to the invention method of operating a gas engine plant comprising a combustion engine adapted to combust gaseous fuel and a fuel feeding system with a source of fuel, comprises at least a step of cracking heavier hydrocarbons in the fuel prior to feeding the fuel into the gas engine in a reformer unit provided in a fuel feeding system of the gas engine. In this manner the quality of the fuel fed to the engine may be maintained at acceptable level even if the fuel originally would include heavy hydrocarbons. In piston engines this means that power output i.e. loading of the engine may be kept at high level without a risk of knocking. Also, the present invention makes it possible to use fuel containing heavier hydrocarbons e.g. in gas turbine designed solely for methane as fuel.
- [0009] Preferable the cracking reactions are controlled so that the heavier hydrocarbons in the fuel are cracked while minimizing cracking of methane. This may be accomplished so that water amount depending on the fuel composition, flow rate, and the reformer unit, is arranged to be present at the reactions, as well as so that temperature of the reformer unit determined for each case is maintained at the reactor unit. In practice the cracking of the heavier hydrocarbons is mainly controlled based on temperature control of the reformer unit. Typically temperature is maintained below 450°C in the reformer unit.
- [0010] It is further advantageous that the fuel, before entering the reformer unit, is heated by transferring heat from the fuel coming out from the reformer unit. This increases energy efficiency of the process.
- [0011] According to a specific embodiment of the invention the source of fuel is liquid fuel and the liquid fuel is evaporated prior to feeding into the reformer unit with heat transferred from the fuel coming out from the reformer unit. Making use of this embodiment a gas engine may be even operated with originally liquid fuel and also with efficient manner.
- [0012] Fuel feeding system of a gas engine according to the invention comprises a supply line for delivering fuel to the gas engine, and the gas engine wherein the supply line is provided with a fuel reformer unit for cracking the heavier hydrocarbons in the fuel prior to feeding to the gas engine.
- [0013] The supply line comprises a first supply line leading from the source of fuel to a reformer unit and a second supply line leading from the reformer unit to the gas engine and the first and the second supply line are provided with a common heat exchanger in which fuel in the first supply line is heated by transferring heat from the fuel in the second supply line. Preferably the fuel reformer unit is provided with temperature controlling device by means of which the temperature in the reformer unit may be

maintained at a level which results in cracking of the heavier hydrocarbons while minimizing the cracking of methane.

[0014] The actual operating parameters for the reformer unit are determined always according to used gas and type of reformer in question.

[0015] In the following, the invention is explained in an exemplary way, with reference to the appended schematic drawings, in which

- figure 1 is an illustration of an embodiment applying the fuel feeding system according to the invention to a gas engine plant, and
- figure 2 is an illustration of an other embodiment applying the fuel feeding system according to the invention to a gas engine plant.

[0016] Figure 1 schematically shows a gas engine plant 1 including a source of fuel 2 and a gas engine 3 as well as a fuel refining unit 4. The gas engine may be e.g. a gas operated piston engine or a gas turbine. Both types of the combustion engines are applicable in connection with the invention.

[0017] The fuel refining unit 4 comprises firstly a filter element 5 provided in a first supply line 12 leading from the source of fuel 2 to a reformer unit 14. The filter unit 5 is provided for separating particles and other solid impurities from the fuel stream. After the filter unit 5 in the fuel flow direction there is a pressure control valve 6 in the first supply line 12. The pressure control valve 6 controls the pressure of the fuel refining unit, which is, when connected to a piston engine, typically approximately 8 bar. The valve 6 is preferably also provided with a safety shut-off valve built into the valve for closing valve outlet in case of a malfunction of the valve 6.

[0018] There is also a shut-off valve 7 in the first supply line and a shut-off valve 8 in the second supply line 13 for separating the fuel refining unit 4 from the system in special cases, like maintenance. Also, before the start up and before maintenance work may be commenced the unit 4 should be made inert, which may be accomplished with a valve 10 and an inlet for inert gas 9, connected here to the first supply line 12 at location after the shut off valve 7. The inert gas may be for example nitrogen. Naturally before starting the maintenance procedures the shut off valves 7, 8 are also closed. The first and the second supply lines may be connected with each other and bypass the refining unit 4 by means of the bypass duct 24. The bypass duct is also provided with a shut off valve 25. It connects the first and the second supply lines at engine/fuel source side of the shut-off valves 7 and 8.

[0019] The unit is preferably provided with a flow meter 11 for example in order to be able to adjust a proper carbon/steam ratio in the process. There is also another flow meter 15 provided in a recycle duct 17. In the recycle duct there is also a high pressure pump 18 for injecting water in the first supply line 12. The recycle duct 17 connects a droplet separator 23 provided in the second supply line 13 to the first supply line 12 at a

location after the flow meter 11. The droplet separator is positioned in the second supply line 13 after a heat exchanger 19, which is connected to the first and second supply lines 12, 13.

[0020] In case the fuel is gaseous the heat exchanger 19 is for heating the gas flowing in the first supply line 12 and cooling the gas in the second supply line 13. In case the refining unit 4 and the combustion engine 3 are used with originally liquid fuel the heat exchanger 19 also evaporates the fuel into gaseous form and heats it and simultaneously cools down the gas coming from the reformer unit 14 on the other side of the heat exchanger 19.

[0021] Additionally, the first supply line 12 is provided with an additional heater 20, like electrical heater for heating the gas to proper temperature before feeding into a sulphur absorber unit 21 provided in the first supply line 12. The sulphur absorber may be needed in case the sulphur content of the fuel is greater than accepted by the reformer unit 14. Here the sulphur absorber is in connection with a reformer unit 14 via a connection line 22. Typically the operation of a steam reformer i.e. reformer in which the reactions of hydrocarbons takes place with water is sensitive to the existence of sulphur. The connection line is in this case also provided with an additional heater 28. It should be noted that all commercially available catalysts feasible for reformer unit do not need complete removal of sulphur from the fuel.

[0022] The operation of refining unit 4 is described in the following. Before the start up the unit 4 is made inert by making use of nitrogen, which is fed through the inlet 9 and the valve 10. The shut off valves 7 and 8 are closed and a vent valve 27 in the vent duct 26 is opened. Nitrogen is led trough the system by opening valve 10. When all oxygen has been flushed from the system, the vent valve 27 is closed and the system is pressurized for example as explained in following.

[0023] A circulation fan 29 in an intermediate duct 30 connecting the first supply line 12 and the second supply line 13 is started and the valve 31 is opened. This way by circulating the nitrogen through the electrical heater(s) 20, 28 the refining unit 4 and the reformer unit 14 as well are heated to operating conditions. As the temperature increases, the pressure will increase accordingly. When the operating conditions have been reached, the high pressure pump 18 will be started to inject water into the nitrogen gas flow according to a pre-programmed C/S (=carbon/steam) ratio (control equipment not shown). C/S ratio is depending on fuel contents and flow rate and it is determined beforehand separately for each case. At least during the start up the water may be introduced into the unit via a water inlet (not shown) provided e.g. in connection with the recycle duct 17. This also depends on the type of used reformer unit 14. When both the sulphur absorber and the reformer reactor has been flushed trough with humid nitrogen, the system is ready for operation. During a normal

operation the bypass duct 24 is closed by shut off valve 25.

[0024] When the fuel refining unit 4 is in normal operation liquid fuel or gas containing heavy hydrocarbons from a fuel source 2 is first filtered in the filter unit 5. After that the fuel is fed into the heat exchanger 19 where it is heated with gas already reformed. It is possible to add water into the fuel stream if needed for obtaining desired carbon/steam ratio in the reformer unit 14 for example through makeup water inlet 32 controlled by valve 33. In case liquid fuel is used as source it is evaporated in the heat exchanger and additionally heated. Now, gaseous fuel after the heat exchanger in the first supply line 12 is heated up to about 300°C being proper temperature for sulphur removal unit 21.

[0025] After possible sulphur has been removed from the gas it is fed to the reformer unit 14. In the reformer the reactions are controlled by maintaining proper temperature therein. For this purpose the reformer unit 14 is provided with heater 37, which may be for example electric heater. The operation of the heater 37 is controlled based on temperature measurement probe 38. It is also possible to use the additional heater 28 based on temperature measurement probe 38 in connection with the reformer unit 14. It is important that the temperature is maintained at a level which will produce only cracking of heavier hydrocarbons in the fuel, while minimizing the cracking of methane. The proper temperature depends on e.g. the actual catalyst used in the reformer unit 14 and on gas composition.

[0026] After the reformer unit 14 the gas is cooled down and the humidity condensed in a heat exchanger 19 at downstream side of the reformer. The water droplets are separated and re-injected into the inlet fuel flow.

[0027] In case the reformer unit is of a type requiring hydrogen present at the reactions, a part of the processed gas will be re-circulated via the intermediate duct 30 and circulation fan 29 back to the first feed duct 12.

[0028] In figure 2 there is shown another embodiment applying the fuel feeding system according to the invention to a gas engine plant. It is mostly identical to the one shown in figure 1 with corresponding reference numbers, but has another type of reformer unit 14. In this case the reformer unit is a so called auto thermal reformer (ATR), the control of which is in some cases gives advantages. ATR type reformer unit 14 is provided with an air introducing duct 34 provided with a control valve 35 and being in connection with a source of pressurized air 36. In ATR it is possible to provide necessary water (steam) into the cracking reactions by controlling the amount of air (or O_2) introduced. By introducing air (or O_2) some of the gas will combust in the reformer unit 14 producing heat and water (steam). This is beneficial because typically the heavier hydrocarbons are the components which are firstly reacting with the oxygen in the air. This way both the adding of steam and controlling the temperature in the

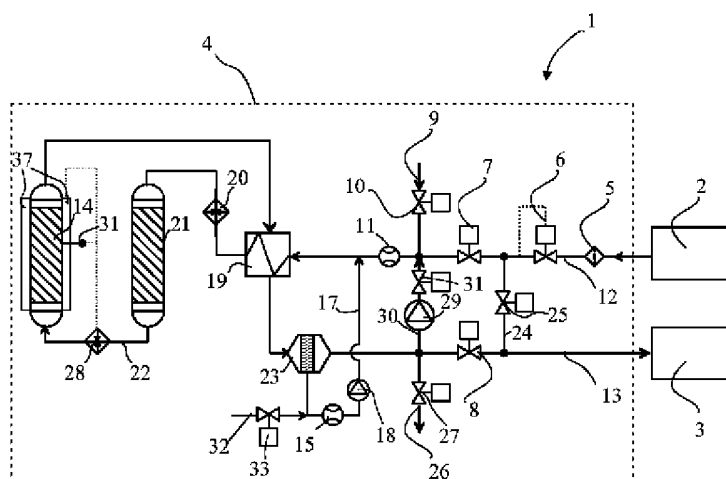
reformer unit 14 may be accomplished by air introduction with ATR reformers.

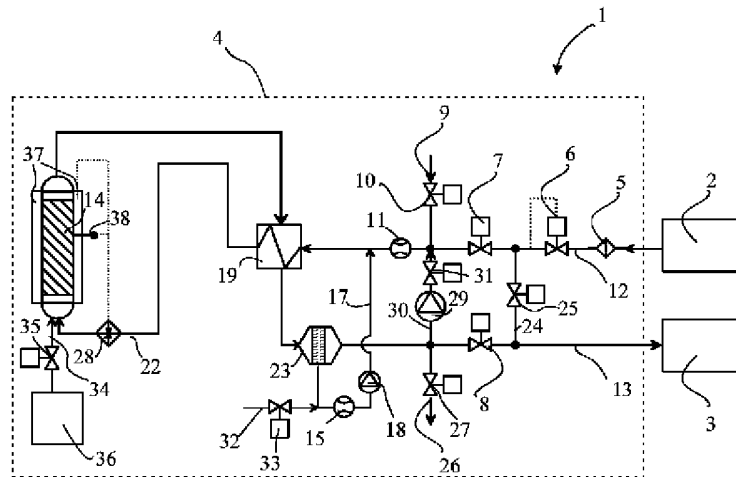
[0029] The invention is not limited to the embodiments described here, but a number of modifications thereof can be conceived of within the scope of the appended claims. For example instead of steam reformer also other types of cracking devices may be utilized. Reformer unit may be formed of several individual units when they can be operated in different manner for obtaining proper gas properties at the end.

Claims

- [0001] Method of operating a gas engine plant (1) comprising a combustion engine (3) adapted to combust gaseous fuel and a fuel feeding system, the method being **characterised** in that heavier hydrocarbons in the fuel are cracked prior to feeding the fuel into the gas engine (3) in a reformer unit (14) provided in a fuel feeding system of the combustion engine (3).
- [0002] Method according to the claim 1, **characterised** in that heavier hydrocarbons in the fuel are cracked while minimizing cracking of methane.
- [0003] Method according to the claim 2, **characterised** in that the cracking of the heavier hydrocarbons is controlled based on temperature control of the reformer unit (14).
- [0004] Method according to the claim 2, **characterised** in that temperature is maintained below 450°C in the reformer unit (14).
- [0005] Method according to any one of the preceding claims, **characterised** in that the fuel, before entering the reformer unit (14), is heated by transferring heat from the fuel coming out from the reformer unit (14).
- [0006] Method according to the claim 1, **characterised** in that the source of fuel (2) is liquid fuel and that the liquid fuel is evaporated prior to feeding into the reformer unit (14) with heat transferred from the fuel coming out from the reformer unit (14).
- [0007] Method according to any one of the preceding claims 1-6, **characterised** in that water required for cracking reaction is introduced (32, 33) into the fuel prior to entering the reformer unit (14).
- [0008] Method according to anyone of the preceding claims 1-6, **characterised** in that water required for cracking reaction is produced in the reformer unit (14) via oxidation reactions of heavier hydrocarbons.
- [0009] Fuel feeding system of a gas engine (3) comprising a supply line (12,13) for delivering fuel to the gas engine (3), **characterised** in that the supply line (12, 13) is provided with a fuel reformer unit (14) for cracking the heavier hydrocarbons in the fuel prior to feeding to the gas engine (3).
- [0010] Fuel feeding system according to the claim 9 **characterised** in that the supply line comprises a first supply line (12) leading from the source of fuel (2) to a reformer unit (14) and a second supply line (13) leading from the reformer unit (14) to the gas engine (3) and that the first and the second supply line are provided with a common heat exchanger (19) in which fuel in the first supply line (12) is heated transferring heat from the fuel in the second supply line (13).
- [0011] Fuel feeding system according to claim 9, **characterised** in that the fuel reformer

unit is provided with temperature controlling device (37,38) for maintaining the reformer unit at proper temperature for cracking the heavier hydrocarbons and minimizing cracking of methane.

**Fig. 1**

**Fig. 2**

INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2006/050087

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02M31/18 F02C7/224 F02B43/00 C10G9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02M F02C F02B C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 147 142 A (LITTLE, DECEASED ET AL) 3 April 1979 (1979-04-03) column 7, line 17 - column 13, line 63; figures -----	1-4,7,9, 11
X	US 5 775 308 A (HEADLEY ET AL) 7 July 1998 (1998-07-07) column 3, line 64 - column 6, line 3; figures -----	1-4,9,11
X	DE 36 07 007 A1 (METZ,HOLGER,DR) 10 September 1987 (1987-09-10) column 7, line 11 - column 8, line 14; figures -----	1,7
X	GB 669 759 A (MICHAEL STEINSCHLAEGER) 9 April 1952 (1952-04-09) page 2, line 21 - line 24 -----	1,8



Further documents are listed in the continuation of Box C.



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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4147142	A	03-04-1979	AU 1198276 A	15-09-1977
			CA 1063458 A1	02-10-1979
			DE 2610688 A1	23-09-1976
			GB 1547252 A	06-06-1979
			JP 51132317 A	17-11-1976
US 5775308	A	07-07-1998	AT 173054 T	15-11-1998
			DE 69505792 D1	10-12-1998
			EP 0744006 A1	27-11-1996
			GB 2290348 A	20-12-1995
			WO 9521997 A1	17-08-1995
			JP 9508689 T	02-09-1997
DE 3607007	A1	10-09-1987	WO 8705363 A1	11-09-1987
			JP 1501885 T	29-06-1989
GB 669759	A	09-04-1952	NONE	