

D E S C R I P T I O N

SHIP

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Technical Field

The present invention relates generally to a ship.

Background Art

In general, ships that generate electric power using diesel generators using liquefied natural gas (LNG) as fuel are known (see, for example, Patent Literature 1).

However, carbon dioxide is generated by burning LNG. Since the generation of carbon dioxide is concerned about the influence to the global environment, its suppression is required.

Citation List

Patent Literature

Patent Literature 1: JP 2020-192895 A

Summary of Invention

Embodiments of the present invention aim to provide a ship that generates electric power while suppressing the emission of carbon dioxide.

A ship according to the aspect of the present invention comprises a gas storage tank storing liquid gas, component separation means for separating hydrogen and carbon dioxide from the gas stored in the gas storage tank, a fuel cell generating electric power with hydrogen separated by the component separation means, and a carbon dioxide storage tank storing carbon dioxide separated by the component separation means.

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Brief Description of Drawings

FIG. 1 is a configuration diagram showing a configuration of a ship according to an embodiment of

the present invention.

FIG. 2 is a schematic diagram showing an overview of energy and material flow in the ship according to the embodiment.

5 FIG. 3 is a configuration diagram showing an example of a configuration for reusing hydrogen contained in steam discharged from a fuel cell according to the embodiment.

10 FIG. 4 is a configuration diagram showing an example of a configuration for cooling mixed gas sent to a carbon dioxide separator according to the embodiment.

15 FIG. 5 is a configuration diagram showing an example of the configuration of a carbon dioxide liquefaction apparatus according to the embodiment.

Mode for Carrying Out the Invention (Embodiment)

20 FIG. 1 is a configuration diagram showing a configuration of a ship 20 according to an embodiment of the present invention. FIG. 2 is a schematic diagram showing an overview of energy and material flow in the ship 20 according to the embodiment. The same portions in the drawings are denoted by the same reference numerals and redundant descriptions are
25 omitted as appropriate.

 The ship 20 is a ship that generates electric power using LNG stored on board as fuel. The ship 20 may be any ship provided with equipment for storing LNG. For example, the ship 20 may be an LNG ship
30 intended to transport LNG, a ship using LNG as a power source fuel and intended to transport objects other than LNG, or a ship intended not to transport objects.

 LNG is used as the fuel for a fuel cell 6, but the

ship may be configured using liquefied petroleum gas (LPG), similarly to LNG. Besides, the fuel of the fuel cell 6 may be any substance as long as it contains hydrogen atoms and carbon atoms. For example, such fuel may be an alcohol such as ethanol or methanol. In addition, a substance which does not contain carbon atoms such as hydrogen or ammonia may be used as a fuel other than the fuel cell 6, or these substances may be used as part of the fuel of the fuel cell 6.

The ship 20 comprises a plurality of LNG tanks 1, a reformer 2, a carbon dioxide separator 3, a carbon dioxide liquefaction device 4, a carbon dioxide storage tank 5, the fuel cell 6, a plurality of solar cells 7, a storage battery 8, a switchboard 9, a DC motor 10, a propeller 11, a steam turbine 12, and a condenser 13.

The LNG tanks 1 are equipment for storing LNG. The LNG tank 1 supplies boil off gas (BOG) to the reformer 2 in accordance with the amount of demand power of the fuel cell 6. BOG is gaseous natural gas that is generated by vaporized LNG stored in the LNG tanks 1 by heat ingress and/or heat input.

The LNG tanks 1 are tanks that store LNG for transportation, on an LNG ship, but may be fuel tanks that store LNG as fuel for the power source. Any number of LNG tanks 1 may be provided as long as the number is one or more.

The reformer 2 is a device that adds high-temperature steam (for example, approximately 900 °C) to the BOG supplied from the LNG tanks 1 to chemically decompose it into mainly two components such as hydrogen and carbon dioxide. For example, the reformer 2 uses steam discharged from the fuel cell 6 as high-temperature steam. This steam may be heated by a

heater and supplied. The reformer 2 adds high-temperature steam to LNG to cause a reforming reaction (endothermic reaction) and a shift reaction, and thereby generates a mixed gas of hydrogen and carbon dioxide. Hydrogen and carbon monoxide are generated by the reforming reaction with methane (LNG) and steam. Furthermore, hydrogen and carbon dioxide are generated by the shift reaction with carbon monoxide and steam. BOG is thereby chemically decomposed into hydrogen and carbon dioxide. The reformer 2 supplies the generated mixed gas of hydrogen and carbon dioxide to the carbon dioxide separator 3.

Hydrogen that has not reacted in the fuel cell 6 is contained in the steam discharged from the fuel cell 6. Therefore, such unreacted hydrogen is reused via the reformer 2 by using the steam discharged from the fuel cell 6. Incidentally, equipment or the like for supplying high-temperature steam to the reformer 2 without using the steam discharged from the fuel cell 6 may be provided separately.

Components other than hydrogen and carbon dioxide may be mixed in the mixed gas after the BOG is decomposed. For example, BOG or carbon monoxide which is not sufficiently decomposed but remains may be mixed or impurities contained in BOG may be mixed.

A carbon dioxide separator (CCS, carbon capture system) 3 physically separates the mixed gas of hydrogen and carbon dioxide chemically decomposed by the reformer 2 into carbon dioxide gas and hydrogen gas. For example, the carbon dioxide separator 3 separates the mixed gas by pressure swing adsorption (PSA) method, but any method may be used to separate the mixed gas. After separating the mixed gas, the

carbon dioxide separator 3 supplies the hydrogen gas to the fuel cell 6 and sends the carbon dioxide gas to the carbon dioxide liquefaction device 4. Incidentally, a compressor C1 for compressing the hydrogen gas may be appropriately provided in a route (for example, a pipeline) for sending the hydrogen gas from the carbon dioxide separator 3 to the fuel cell 6.

The carbon dioxide liquefaction device 4 cools the carbon dioxide gas sent from the carbon dioxide separator 3 to liquefy carbon dioxide. The carbon dioxide liquefaction device 4 makes the liquefied carbon dioxide to be stored in the carbon dioxide storage tank 5. By thus storing carbon dioxide in the carbon dioxide storage tank 5, the emission of carbon dioxide during navigation of the ship 20 is suppressed.

The carbon dioxide storage tank 5 may be installed detachably from the ship 20, or may be configured to be connected to a transport pump to send the liquefied carbon dioxide overboard, or may have both of the configurations. In addition, a cargo handling pump may be provided in the carbon dioxide storage tank 5 in addition to the transport pump in order to take out the carbon dioxide stored in the carbon dioxide storage tank 5. The carbon dioxide stored in the carbon dioxide storage tank 5 can be thus carried ashore and disposed of freely. The carbon dioxide stored in the carbon dioxide storage tank 5 may be disposed of by being sequestered in the underground, or may be used for applications that require carbon dioxide as a resource.

For example, the reformer 2, the carbon dioxide separator 3, and the carbon dioxide liquefaction device 4 may be installed together in one building BD of the

ship 20. As a result, these devices 2 to 4 can be protected from external factors such as salt damage, and the route (for example, pipeline) for sending substances (carbon dioxide, etc.) can be shortened. In addition, the carbon dioxide storage tank 5 is desirably installed near the carbon dioxide liquefaction device 4 and at a location where the carbon dioxide stored therein can easily be landed.

The fuel cell 6 is a solid oxide fuel cell (SOFC) that generates electric power using oxygen in the air taken in from the atmosphere and hydrogen gas supplied by the carbon dioxide separator 3. The fuel cell 6 supplies the generated electric power to the DC motor 10 via the switchboard 9.

In addition, the fuel cell 6 may supply the generated electric power to electrical equipment on board other than the DC motor 10. Steam containing hydrogen discharged from the fuel cell 6 and remaining unreacted is sent to the reformer 2 and the steam turbine 12. The fuel cell 6 is described as a solid oxide type, but other types of fuel cells may be applied. In addition, the fuel cell 6 may be installed inside the building to be protected from external factors such as salt damage.

The solar cell 7 is a cell that converts sunlight into electric energy. The solar cell 7 is installed in a place (for example, a deck or the like) on the surface side of the ship 20, which is irradiated with sunlight. The solar cell 7 supplies the generated electric power to the DC motor 10 via the switchboard 9. In addition, the solar cell 7 may supply the generated electric power to electric equipment on board other than the DC motor 10. Incidentally, the solar

cell 7 may not be provided on the ship 20.

The storage battery 8 is connected to the switchboard 9. When the demanded power supplied to the DC motor 10 and the like is greater than the electric power supplied from the fuel cell 6 and the solar cell 7, the storage battery 8 supplements the supplied power with the stored electric energy. In contrast, when the demanded power is less than the power supplied from the fuel cell 6 and the solar cell 7, the storage battery 8 is charged. Thus, the storage battery 8 is charged and discharged so as to balance the demanded power and the supplied power. Incidentally, the storage battery 8 may not be provided on the ship 20.

Each of the fuel cell 6 and the solar cell 7 may comprise a control unit for controlling the own operations, and a power converter for converting the output power into desired power. Similarly, the storage battery 8 may include a controller for controlling its own operation (charging, discharging, or the like) and a power converter for converting charging/discharging power into desired power.

The switchboard 9 is a device for supplying electric power supplied from the fuel cell 6, the solar cell 7, and the storage battery 8 to the DC motor 10 and the like. When the storage battery 8 is charged, the switchboard 9 supplies the storage battery 8 with electric energy supplied from the fuel cell 6 and the solar cell 7. Any number of switchboards 9 may be provided, or the switchboards 9 may be eliminated and switches or the like may be provided instead.

The DC motor 10 is a power source for obtaining a propulsive force for the ship 20. Since the DC motor 10 is driven by the DC power supplied from the fuel

cell 6, the solar cell 7, and the storage battery 8, the number of power conversion circuits such as inverters can be reduced and overall energy efficiency of the ship 20 is improved as compared to a case where an AC motor is used. Incidentally, an AC motor may be used instead of the DC motor 10.

The propeller 11 is a device that is connected to the DC motor 10 to convert the rotational force of the DC motor 10 into the propulsive force of the ship 20.

The steam turbine 12 performs steam turbine power generation using the steam exhausted from the fuel cell 6. For example, the steam remaining after removing the steam necessary for the reformer 2, of the steam exhausted from the fuel cell 6, is sent to the steam turbine 12. Incidentally, all of the steam exhausted from the fuel cell 6 may be sent to the steam turbine 12 and may not be sent to the reformer 2. In addition, the power generation using the steam turbine 12 may be used in any manner. For example, the steam turbine 12 may supply generated electric power to the switchboard 9. Incidentally, the steam exhausted from the fuel cell 6 may be sent directly to the condenser 13 without providing the steam turbine 12.

The condenser 13 is connected to the steam turbine 12. The condenser 13 converts the steam sent from the fuel cell 6 through the steam turbine 12 back into water and extracts hydrogen contained in the steam. The condenser 13 supplies the hydrogen extracted from the steam to the fuel cell 6 as fuel. The hydrogen extracted from the condenser 13 is reused in the fuel cell 6 in this manner. In addition, the water extracted from the condenser 13 may be reused or discarded. When draining water from the condenser 13

to the outside, a condensate pump for draining water may be provided.

FIG. 3 is a configuration diagram showing an example of a configuration for reusing hydrogen contained in the steam discharged from the fuel cell 6 according to the embodiment. The configuration is not limited to that described here, but any configuration may be used.

A vacuum pump P1 and a separator SP are provided in a route (for example, a pipeline) for supplying hydrogen gas from the condenser 13 to the fuel cell 6.

A gas containing a large amount of hydrogen is supplied from the condenser 13 to the vacuum pump P1. The vacuum pump P1 sends the hydrogen-rich gas supplied from the condenser 13, to the separator SP, while keeping the condenser 13 in a vacuum state. The separator SP removes impurities (such as water, carbon dioxide, or the like) other than hydrogen gas from the gas supplied from the vacuum pump P1. The separator SP thereby extracts hydrogen gas with high purity. The separator SP supplies the extracted hydrogen gas to the fuel cell 6. A compressor for compressing the hydrogen gas may be provided in the route through which the separator SP sends the hydrogen gas to the fuel cell 6.

FIG. 4 is a configuration diagram showing an example of a configuration for cooling the mixed gas sent to the carbon dioxide separator 3 in the embodiment.

Since the mixed gas of hydrogen and carbon dioxide discharged from the reformer 2 has a high temperature exceeding a permissible temperature of the carbon dioxide separator 3, the mixed gas cannot be sent to the carbon dioxide separator 3 unless cooled.

Therefore, a cooler 31 for cooling the mixed gas is provided in the middle of the route (for example, pipeline) of the mixed gas sent from the reformer 2 to the carbon dioxide separator 3. A configuration in a case where two heat exchangers 32 and 33 are provided in addition to the cooler 31 will be described with reference to FIG. 4.

The first heat exchanger 32 cools the mixed gas of hydrogen and carbon dioxide discharged from the reformer 2 with the hydrogen gas supplied as fuel from the carbon dioxide separator 3 or the condenser 13 to the fuel cell 6. As a result, the mixed gas is cooled and the hydrogen gas supplied to the fuel cell 6 as fuel is heated. Therefore, the mixed gas can be cooled and the hydrogen gas used as fuel for the fuel cell 6 can be heated.

The second heat exchanger 33 cools the mixed gas cooled by the first heat exchanger 32 with oxygen (air) taken in as fuel by the fuel cell 6. As a result, the mixed gas is cooled and the air taken into the fuel cell 6 as fuel is heated. Therefore, the mixed gas can be cooled and the oxygen (air) used as fuel for the fuel cell 6 can be heated.

The cooler 31 cools the mixed gas discharged from the reformer 2 and cooled by the two heat exchangers 32 and 33 to a temperature lower than or equal to the permissible temperature of the carbon dioxide separator 3. The cooler 31 thus sends the mixed gas cooled to the temperature lower than or equal to the permissible temperature to the carbon dioxide separator 3.

Incidentally, any number of coolers 31 may be provided. In addition, any number of heat exchangers 32 and 33 may be provided or may not be provided.

Furthermore, the order of cooling by coolers and heat exchangers may be determined arbitrarily.

FIG. 5 is a configuration diagram showing an example of the configuration of the carbon dioxide liquefaction device 4 according to the embodiment. The configuration of the carbon dioxide liquefaction device 4 described here is just an example, and any configuration may be used as long as the carbon dioxide gas can be liquefied.

The carbon dioxide liquefaction device 4 comprises a carbon dioxide compressor 41, a dehumidifier 42, a first heat exchanger 43, a carbon dioxide liquefier 44, a refrigerator 45, a refrigerant condenser 46, and a second heat exchanger 47.

The carbon dioxide compressor 41 takes in and compresses the carbon dioxide gas separated by the carbon dioxide separator 3. The carbon dioxide compressor 41 sends the compressed carbon dioxide gas to the dehumidifier 42. In addition, the carbon dioxide compressor 41 may also take in carbon dioxide vaporized inside the carbon dioxide storage tank 5 in addition to the carbon dioxide gas from the carbon dioxide separator 3 and compress them together.

The dehumidifier 42 dries the carbon dioxide gas sent from the carbon dioxide compressor 41. A purge gas is thereby released from the carbon dioxide gas. The dehumidifier 42 sends the dried carbon dioxide gas to the first heat exchanger 43. The dehumidifier 42 may not be provided.

The first heat exchanger 43 cools the carbon dioxide gas sent from the dehumidifier 42 with fresh water. Fresh water is cooling water prepared in advance in the ship. Water (seawater or the like)

pumped up from the outside of the ship by a water intake pump or the like may be used instead of fresh water. The first heat exchanger 43 sends the cooled carbon dioxide gas to the carbon dioxide liquefier 44.

5 The carbon dioxide liquefier 44 cools and liquefies the carbon dioxide gas sent from the first heat exchanger 43. Noncondensable gases that are not condensed thereby escape from the carbon dioxide. The carbon dioxide liquefier 44 sends the liquefied carbon dioxide to the second heat exchanger 47.

10 The carbon dioxide liquefier 44 cools the carbon dioxide gas with a refrigerant. The refrigerant used to cool the carbon dioxide gas is sent to the refrigerator 45 and cooled. The refrigerant cooled by the refrigerator 45 is sent to the refrigerant condenser 46 and compressed. The refrigerant compressed by the refrigerant condenser 46 is supplied to the carbon dioxide liquefier 44 and used to cool the carbon dioxide gas.

20 The second heat exchanger 47 cools the liquefied carbon dioxide sent from the carbon dioxide liquefier 44 by the BOG. The second heat exchanger 47 cools and sends the liquefied carbon dioxide to the carbon dioxide storage tank 5.

25 According to the embodiment, the following advantages can be obtained.

30 By separating the BOG into hydrogen and carbon dioxide, removing the carbon dioxide, and supplying only hydrogen as fuel to the fuel cell 6, the recovery of carbon dioxide can be performed more easily than supplying the BOG directly to the fuel cell 6 as the fuel. The amount of carbon dioxide discharged to the outside of the ship can be thereby suppressed.

By using the steam discharged from the fuel cell 6 as the high-temperature steam necessary to cause the reforming reaction to be made in the reformer 2, the overall energy efficiency can be increased and the equipment costs of the ship 20 can be reduced as compared to providing the device for producing high-temperature steam alone. In addition, since hydrogen is contained in the steam discharged from the fuel cell 6, the consumption efficiency of hydrogen contained in the LNG can be improved.

By providing the condenser 13 and extracting the hydrogen contained in the steam discharged from the fuel cell 6, the consumption efficiency of hydrogen contained in the LNG can be improved.

By providing the steam turbine 12 in the middle of the route through which the steam is discharged from the fuel cell 6 to the condenser 13, electric power can be generated by the steam discharged from the fuel cell 6.

The heat exchangers 32 and 33 are provided, and the mixed gas discharged from the reformer 2 is cooled by utilizing hydrogen supplied from the carbon dioxide separator 3 to the fuel cell 6 and the air used for the power generation in the fuel cell 6. The inlet temperature of the mixed gas at the cooler 31 can be thereby made lower than that in a case of cooling the mixed gas without providing the heat exchangers 32 and 33. Therefore, the mixed gas can be efficiently cooled, and the cooler 31 with a lower cooling capacity can be adopted. In addition, since hydrogen and the air supplied to the fuel cell 6 are also heated, the power generation efficiency of the fuel cell 6 can be improved.

By using the BOG to cool carbon dioxide in the carbon dioxide liquefaction device 4, the energy efficiency of cooling carbon dioxide can be improved. In addition, the energy efficiency can be further improved by using outboard water such as seawater for cooling.

The present invention is not limited to the above-described embodiment, and constituent elements may be deleted, added, modified and the like. In addition, the constituent elements in more than one embodiment may be combined, replaced or the like to constitute a new embodiment. Even if such an embodiment is directly different from the above-described embodiment, the embodiment having the same spirit as the present invention is considered as being explained as the embodiment of the present invention, and explanation is omitted.

C L A I M S

1. A ship characterized by comprising:

a gas storage tank storing liquid gas;

component separation means for separating hydrogen
5 and carbon dioxide from the gas stored in the gas
storage tank;

a fuel cell generating electric power with
hydrogen separated by the component separation means;
and

10 a carbon dioxide storage tank storing carbon
dioxide separated by the component separation means.

2. The ship of claim 1, characterized in that the
component separation means includes:

reforming reaction means for chemically
15 decomposing the gas into hydrogen and carbon dioxide by
a reforming reaction; and

mixed gas separation means for separating hydrogen
and carbon dioxide from mixed gas containing hydrogen
and carbon dioxide decomposed by the reforming reaction
20 means.

3. The ship of claim 2, characterized in that the
reforming reaction means causes the reforming reaction
to be made using steam discharged from the fuel cell.

4. The ship of claim 2, characterized by further
25 comprising:

cooling means for cooling the mixed gas to be sent
to the mixed gas separation means.

5. The ship of claim 4, characterized in that the
cooling means includes cooling the mixed gas using
30 hydrogen separated by the reforming reaction means.

6. The ship of claim 4, characterized in that the
cooling means includes cooling the mixed gas using air
taken in the fuel cell.

7. The ship of claim 1, characterized by further comprising:

hydrogen extraction means for extracting hydrogen contained in steam discharged from the fuel cell.

5 8. The ship of claim 1, characterized by further comprising:

carbon dioxide liquefaction means for liquefying carbon dioxide separated by the component separation means in order to store in the carbon dioxide storage tank.

10 9. The ship of claim 8, characterized in that the carbon dioxide liquefaction means liquefies carbon dioxide using boil off gas (BOG) generated in the gas storage tank.

15 10. The ship of claim 8, characterized in that the carbon dioxide liquefaction means liquefies carbon dioxide using outboard water.

11. The ship of claim 1, characterized by further comprising:

20 a motor obtaining a propulsive force of the ship with an electric power generated by the fuel cell.

12. The ship of claim 11, characterized in that the motor includes a DC motor driving with DC power.