

SHIP ENGINE OPERATING METHOD

【TECHNICAL FIELD】

[1] The present invention relates to a ship engine operation method for a ship including engines capable of being simultaneously fueled by natural gas and fuel oil.

【BACKGROUND ART】

[2] Generally, natural gas is liquefied and transported over a long distance in the form of liquefied natural gas (LNG). Liquefied natural gas is obtained by cooling natural gas to a very low temperature of about -163°C at atmospheric pressure and is well suited to long-distance transportation by sea, since the volume thereof is significantly reduced, as compared with natural gas in a gas phase.

[3] Even when an LNG storage tank is insulated, there is a limit to completely block external heat. Thus, LNG is continuously vaporized in the LNG storage tank by heat transferred into the storage tank. LNG vaporized in the storage tank is referred to as boil-off gas (BOG).

[4] If the pressure in the storage tank exceeds a predetermined safe pressure due to generation of boil-off gas, the boil-off gas is discharged from the storage tank through a safety valve. The boil-off gas discharged from the storage tank is used as fuel for a ship or is reliquefied and returned to the storage tank.

[5] Examples of a ship engine capable of being fueled by natural gas include gas-fueled engines such as a DFDE, an ME-GI engine, and an X-DF engine.

[6] The DFDE is a four stroke power generation engine. Specifically, the DFDE uses an Otto cycle, in which natural gas at a relatively low pressure of about 6.5 bar is injected into a combustion air inlet and then compressed by a piston moving upward.

[7] The ME-GI engine is a two stroke propulsion engine. Specifically, the ME-GI engine uses a diesel cycle, in which natural gas at a high pressure of about 300 bar is injected directly into a combustion chamber near the top dead point of a piston.

[8] The X-DF engine is a two stroke propulsion engine. Specifically, the X-DF

engine is fueled by natural gas at a medium pressure of about 16 bar and uses an Otto cycle.

【DISCLOSURE】

【Technical Problem】

[9] It is an aspect of the present invention to provide an efficient ship engine operation method for a ship including engines capable of being simultaneously fueled by natural gas and fuel oil.

【Technical Solution】

[10] In accordance with one aspect of the present invention, a ship engine operation method includes: a first step in which gas consumption of a first engine at each gas rate of the first engine is determined while changing the gas rate from 0% to 100% for a given current load of the first engine; a second step in which fuel oil consumption of the first engine at each gas rate of the first engine is determined while changing the gas rate from 0% to 100% for the given current load of the first engine; a third step in which an amount of gas available for combustion in a second engine at each gas rate of the first engine is calculated while changing the gas rate from 0% to 100% for the given current load of the first engine; a fourth step in which a gas rate of the second engine is determined for each amount of gas available for combustion in the second engine determined in the third step; a fifth step in which fuel oil consumption of the second engine for a given current load of the second engine is calculated for each gas rate of the second engine determined in the fourth step; a sixth step in which the total fuel oil consumption is calculated by adding the fuel oil consumption of the first engine calculated in the second step to the fuel oil consumption of the second engine calculated in the fifth step; and a seventh step in which a command is sent to the first engine and the second engine to operate the first engine and the second engine at respective gas rates at which the total fuel oil

consumption calculated in the sixth step has a minimum value, wherein the first engine and the second engine are operated in a fuel sharing mode.

[11] In the first step, the gas consumption of the first engine may be determined based on a natural gas efficiency table for the first engine, wherein the natural gas efficiency table may show natural gas consumption depending on natural gas rate for each engine load.

[12] In the second step, the fuel oil consumption of the first engine may be determined based on a fuel oil efficiency table for the first engine, wherein the fuel oil efficiency table may show fuel oil consumption depending on fuel oil rate for each engine load.

[13] In the third step, the amount of gas available for combustion in the second engine may be calculated by subtracting the gas consumption of the first engine determined in the first step from the total amount of currently available natural gas.

[14] The total amount of currently available natural gas may be equal to the total amount of boil-off gas discharged from a storage tank.

[15] In the fourth step, the gas rate of the second engine may be determined based on a natural gas efficiency table for the second engine, wherein the natural gas efficiency table may show natural gas consumption depending on natural gas rate for each engine load.

[16] The current load of the second engine may be equal to the current load of the first engine.

[17] The fifth step may include: calculating "energy to be produced by fuel oil" of the second engine by subtracting "energy produced by gas available for combustion" of the second engine from "energy to be produced by consuming fuel" determined by the current load of the second engine; and calculating "fuel oil consumption" of the second engine by dividing the "energy to be produced by fuel oil" of the second engine by "calorific value of fuel oil per unit volume".

[18] The first engine and the second engine may be X-DF engines.

[19] In accordance with another aspect of the present invention, a ship engine operation method includes: calculating fuel oil consumption of each of multiple X-DF engines at each gas rate thereof for a given current load of each of the X-DF

engines determined by speed of a ship; and determining respective gas rates of the multiple X-DF engines at which the total fuel oil consumption of the multiple X-DF engines has a minimum value, wherein the multiple X-DF engines are each operated in a fuel sharing mode.

【Advantageous Effects】

[20] The present invention provides a ship engine operation method which can operate multiple engines at the lowest cost for a given current engine load.

【DESCRIPTION OF DRAWINGS】

[21] FIG. 1 is a flowchart of a ship engine operation method according to one embodiment of the present invention.

[22] FIG. 2 is a logic flow diagram of factors of the ship engine operation method according to one embodiment of the present invention.

【BEST MODE】

[23] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. A ship employing a ship engine operation method according to the present invention may include various ships such as LNG carriers, LNG-fueled ships, drilling ships, and offshore structures. In addition, the ship engine operation method according to the present invention may be applied to any engines capable of being fueled by both fuel oil and natural gas. It should be understood that the following embodiments can be modified in various ways and do not limit the scope of the present invention.

[24]

[25] Typical dual-fuel (DF) engines capable of being fueled by both fuel oil and natural gas cannot use fuel oil and natural gas as fuel at the same time. That is, such a DF engine can be operated in either a fuel oil mode (FO mode) or a gas mode.

[26] A fuel sharing mode (FSM) refers to a mode in which a DF engine is fueled by natural gas and fuel oil at the same time. That is, existing DF engines capable of operation in either a gas Mode or an FO mode have been improved to avoid reduction in combustion performance even upon simultaneous injection of fuel oil and gas, thereby allowing operation in the fuel sharing mode as well as in the gas mode and the fuel oil mode.

[27] Advantageously, an engine capable of operation in the fuel sharing mode (FSM) makes better use of boil-off gas generated in a storage tank than typical engines operated in either the gas mode or the fuel oil mode.

[28] An engine to which the ship engine operation method according to the present invention is applied is an engine that is operated in any one of the gas mode, the fuel oil mode, and the fuel sharing mode, and the ship engine operation method according to the present invention is aimed at determining a ratio of natural gas and fuel oil used in each engine allowing minimization of fuel cost when multiple engines are each operated in the fuel sharing mode.

[29]

[30] FIG. 1 is a flowchart of a ship engine operation method according to one embodiment of the present invention.

[31] Referring to FIG. 1, the ship engine operation method according to this embodiment includes a first step S10 in which gas consumption of a first engine at each gas rate of the first engine is determined while changing the gas rate from 0% to 100% for a given current load of the first engine.

[32] Here, current load of an engine may be determined by required speed of a ship depending on the operational conditions of the ship. The ship engine operation method according to this embodiment is aimed at determining a gas rate allowing minimization of fuel cost for a given current engine load.

[33] For each engine, manufacturers may provide an efficiency table upon using fuel oil as fuel and an efficiency table upon using natural gas as fuel. The fuel oil efficiency table shows fuel oil consumption depending on fuel oil rate for each engine load and a natural gas efficiency table shows natural gas consumption depending on natural gas rate for each engine load.

[34] Here, the natural gas rate refers to the proportion of natural gas in a fuel used in an engine operating in the fuel sharing mode, and the fuel oil rate refers to the proportion of fuel oil in the fuel used in the engine operating in the fuel sharing mode. Since an engine operating in the fuel sharing mode is fueled by natural gas and fuel oil at the same time, the sum of the natural gas rate and the fuel oil rate for one engine is 100%.

[35] In the first step S10, the gas consumption of the first engine at each gas rate for the given current load may be determined based on the natural gas efficiency table for the first engine.

[36]

[37] The ship engine operation method according to this embodiment includes a second step S20 in which fuel oil consumption of the first engine at each gas rate of the first engine is determined while changing the gas rate from 0% to 100% for the given current load of the first engine.

[38] In the second step S20, the fuel oil consumption of the first engine at each fuel oil rate for the given current load may be determined based on the fuel oil efficiency table for the first engine. Since the sum of the fuel oil rate and the gas rate is 100%, the fuel oil consumption of the first engine at each gas rate for the given current load can be determined.

[39] Through the first step S10 and the second step S20, the gas consumption and fuel oil consumption of the first engine at each gas rate for the given current load can be determined.

[40]

[41] The ship engine operation method according to this embodiment includes a third step S30 in which an amount of gas available for combustion in a second engine at each gas rate of the first engine is calculated while changing the gas rate from 0% to 100% for the given a current load of the first engine.

[42] Generally, the amount of natural gas available to a ship is limited. For example, for a ship such as an LNG carrier, it is economical to refrain from using liquefied natural gas, which is freight carried by the ship, as much as possible, and it is effective to use boil-off gas generated by natural vaporization of LNG in an engine

to reduce explosion risk of a storage tank. Accordingly, the amount of natural gas available to the ship may be defined by the total amount of boil-off gas discharged from the storage tank.

[43] When the amount of natural gas available to the ship is defined by the total amount of boil-off gas discharged from the storage tank, the sum of the "gas consumption of the first engine" determined in the first step S10 and the "amount of gas available for combustion in the second engine" may be equal to the "total amount of boil-off gas discharged from the storage tank".

[44] That is, in the third step S30, the amount of gas available for combustion in the second engine at each gas rate of the first engine may be calculated by subtracting the gas consumption of the first engine determined in the first step S10 from the total amount of boil-off gas currently discharged from the storage tank.

[45]

[46] The ship engine operation method according to this embodiment includes a fourth step S40 in which a gas rate of the second engine is determined for each amount of gas available for combustion in the second engine determined in the third step S30.

[47] Since the current load of the second engine can be known, in the fourth step S40, the gas rate of the second engine for each amount of gas available for combustion in the second engine for a given current load of the second engine can be determined based on the natural gas efficiency table for the second engine. Here, the current load of the second engine may be equal to the current load of the first engine.

[48] Although the expression "gas consumption" is used with respect to the first engine in the first step S10 and the expression "amount of gas available for combustion" is used with respect to the second engine in order to emphasize that the amount of gas consumed by the second engine is determined by the amount of gas consumed by the first engine and the amount of available natural gas, "gas consumption" has the same meaning as the "amount of gas available for combustion" in the natural gas efficiency table. In other words, "gas consumption" of the first engine and the "amount of gas available for combustion" in the second engine are values listed in the same section in the respective efficiency tables for the first engine and the second engine.

[49]

[50] The ship engine operation method according to this embodiment includes a fifth step S50 in which fuel oil consumption of the second engine for the given current load of the second engine is calculated for each gas rate of the second engine determined in the fourth step S40.

[51] Since "energy to be produced by fuel consumption" for the given current load of the second engine is given and the amount of gas available for combustion in the second engine is determined in the third step S30, "energy to be produced by fuel oil" of the second engine can be calculated by subtracting "energy produced by gas available for consumption" of the second engine from "energy to be produced by fuel consumption" of the second engine for the given current load of the second engine.

[52] When the "energy to be produced by fuel consumption" of the second engine is known, "fuel oil consumption" of the second engine can be calculated by dividing the "energy to be produced by fuel oil" of the second engine by "calorific value of fuel oil per unit volume".

[53] Since the "amount of gas available for combustion" of the second engine varies depending on the "gas rate" of the second engine, in the fifth step S50, the fuel oil consumption of the second engine depending on the gas rate of the second engine can be calculated.

[54]

[55] The ship engine operation method according to this embodiment includes a sixth step S60 in which the total fuel oil consumption is calculated by adding the fuel oil consumption of the first engine calculated in the second step S20 to the fuel oil consumption of the second engine calculated in the fifth step S50.

[56] Since fuel oil is generally more expensive than natural gas, it may be said that minimization of fuel oil consumption means minimization of fuel cost. Accordingly, in the sixth step S60, the amounts of fuel oil consumed in the first engine and the second engine are summed in order to determine a case in which the total fuel oil consumption of the first engine and the second engine has a minimum value.

[57] Although this embodiment has been described using an example in which the present invention is applied to two engines, it should be understood that the present

invention is not limited thereto and may be applied to multiple engines. In addition, although the first engine and the second engine are preferably X-DF engines, it should be understood that the present invention is not limited thereto. However, the present invention may be particularly suited to a ship equipped with two X-DF engines.

[58]

[59] The ship engine operation method according to this embodiment includes a seventh step S70 in which a command is sent to the first engine and the second engine to operate the first engine and the second engine at respective gas rates at which the total fuel oil consumption calculated in the sixth step S60 has a minimum value.

[60]

[61] FIG. 2 is a logic flow diagram of factors of the ship engine operation method according to one embodiment of the present invention.

[62] Referring to FIG. 2, in the ship engine operation method according to this embodiment, when a gas rate of the first engine S110 is determined, gas consumption of the first engine S120, fuel oil consumption of the first engine S130, and an amount of gas available for combustion in the second engine S140 can be determined. In addition, when the amount of gas available for combustion in the second engine S140 is determined, a gas rate of the second engine S150 can be determined and fuel oil consumption of the second engine S160 depending on the gas rate of the second engine S150 can be determined.

[63] Therefore, according to this embodiment, it can be seen that a gas rate of the first engine S110 and a gas rate of the second engine S150 allowing minimization of the total fuel oil consumption can be determined by determining a value of fuel oil consumption of the first engine S130 and a value of fuel oil consumption of the second engine S160 when the sum of fuel oil consumption of the first engine S130 and fuel oil consumption of the second engine S160 has a minimum value.

[64]

[65] Although some embodiments have been described herein, it should be understood that these embodiments are provided for illustration only and are not to be construed in any way as limiting the present invention, and that various modifications, changes, alterations, and equivalent embodiments can be made by those skilled in the

art without departing from the spirit and scope of the invention.

【CLAIMS】

【Claim 1】

A ship engine operation method comprising:

a first step in which gas consumption of a first engine at each gas rate of the first engine is determined while changing the gas rate from 0% to 100% for a given current load of the first engine;

a second step in which fuel oil consumption of the first engine at each gas rate of the first engine is determined while changing the gas rate from 0% to 100% for the given current load of the first engine;

a third step in which an amount of gas available for combustion in a second engine at each gas rate of the first engine is calculated while changing the gas rate from 0% to 100% for the given current load of the first engine;

a fourth step in which a gas rate of the second engine is determined for each amount of gas available for combustion in the second engine determined in the third step;

a fifth step in which fuel oil consumption of the second engine for a given current load of the second engine is calculated for each gas rate of the second engine determined in the fourth step;

a sixth step in which the total fuel oil consumption is calculated by adding the fuel oil consumption of the first engine calculated in the second step to the fuel oil consumption of the second engine calculated in the fifth step; and

a seventh step in which a command is sent to the first engine and the second engine to operate the first engine and the second engine at respective gas rates at which the total fuel oil consumption calculated in the sixth step has a minimum value,

wherein the first engine and the second engine are operated in a fuel sharing mode.

【Claim 2】

The ship engine operation method according to claim 1, wherein, in the first step, the gas consumption of the first engine is determined based on a natural gas efficiency table for the first engine, the natural gas efficiency table showing natural gas consumption depending on natural gas rate for each engine load.

【Claim 3】

The ship engine operation method according to claim 1, wherein, in the second step, the fuel oil consumption of the first engine is determined based on a fuel oil efficiency table for the first engine, the fuel oil efficiency table showing fuel oil consumption depending on fuel oil rate for each engine load.

【Claim 4】

The ship engine operation method according to claim 1, wherein, in the third step, the amount of gas available for combustion in the second engine is calculated by subtracting the gas consumption of the first engine determined in the first step from the total amount of currently available natural gas.

【Claim 5】

The ship engine operation method according to claim 4, wherein the total amount of currently available natural gas is equal to the total amount of boil-off gas discharged from a storage tank.

【Claim 6】

The ship engine operation method according to claim 1, wherein, in the fourth step, the gas rate of the second engine is determined based on a natural gas efficiency table for the second engine, the natural gas efficiency table showing natural gas consumption depending on natural gas rate for each engine load.

【Claim 7】

The ship engine operation method according to claim 1, wherein the current load of the second engine is equal to the current load of the first engine.

【Claim 8】

The ship engine operation method according to claim 1, wherein the fifth step comprises:

calculating "energy to be produced by fuel oil" of the second engine by subtracting "energy produced by gas available for combustion" of the second engine from "energy to be produced by fuel consumption" determined by the current load of the second engine; and

calculating "fuel oil consumption" of the second engine by dividing the "energy to be produced by fuel oil" of the second engine by "calorific value of fuel oil per unit volume".

【Claim 9】

The ship engine operation method according to any one of claims 1 to 8, wherein the first engine and the second engine are X-DF engines.

【Claim 10】

A ship engine operation method comprising:

calculating fuel oil consumption of each of multiple X-DF engines at each gas rate thereof for a given current load of each of the X-DF engines determined by speed of a ship; and

determining respective gas rates of the multiple X-DF engines at which the total fuel oil consumption of the multiple X-DF engines has a minimum value,

wherein the multiple X-DF engines are each operated in a fuel sharing mode.