

AIR LUBRICATION SYSTEM FOR SHIPS

FIELD

[0001] The present invention relates to an air lubrication system, and more particularly to an air lubrication system for ships, which can reduce frictional resistance of a ship by forming an air layer on a hull surface.

BACKGROUND

[0002] During navigation of a ship, a hull of the ship is subjected to wave resistance, viscous resistance, and air resistance. In order to reduce such resistance, most ships are streamlined.

[0003] Wave resistance is due to regular waves created by the bow of the ship during propulsion thereof through the water and acts perpendicular to the entire region of the hull, causing energy loss of the ship. Viscous resistance is due to viscosity of water and is generally classified into frictional resistance and form resistance. Thereamong, frictional resistance refers to drag force hindering travel of a ship, which is due to viscous adhesion of seawater to a wetted surface of the hull.

[0004] In order to reduce frictional resistance, there have been proposed various solutions, such as design of a hydrofoil adapted to minimize a contact area between seawater and the hull, design of an air lubrication ship adapted to improve conditions of the wetted surface and bottom of the hull, and design of a supercavitating underwater vehicle.

[0005] As another solution to reduce frictional resistance, there has been proposed an air lubrication system that can reduce energy loss due to viscosity of seawater by forming an air layer on a hull surface to prevent the hull surface from contacting seawater.

[0006] A general air lubrication system reduces frictional resistance by creating an air cavity on the surface of the hull to reduce a wetted surface area of the ship, and thus is very environmentally friendly and is easy to apply to actual ships.

[0007] FIG. 1 is a diagram of a typical air lubrication system.

[0008] Referring to FIG. 1, the air lubrication system includes an air ejector 11 disposed at the bow of a hull 20, two air compressors 13, 14 disposed adjacent to the air ejector 11, and two motors 15, 16 disposed adjacent to the air ejector 11 to drive the air compressors 13, 14. In addition, the air lubrication system may include a distribution board 17 to drive the motors 15, 16. Further, the air lubrication system includes an air delivery pipe AP connected between the air ejector 11 and the air compressors 13, 14.

[0009] A power generation engine GE is disposed at the stern of the hull. The distribution board 17 receives electricity from the power generation engine GE and distributes the received electricity to the motors 15, 16. In addition, a main engine ME may be disposed at the stern of the hull.

[0010] The power generation engine GE may include multiple power generation engines. Here, a switchboard SB may be provided to manage electricity generated by the power generation engines GE. That is, the switchboard SB may be electrically connected to the distribution board 17.

[0011] Although not shown, the air lubrication system may further include a device for regulating the amount of air discharged from the air ejector 11, as needed.

[0012] <Related Literature>

[0013] <Patent Document>

[0014] (Patent Document 1) Korean Patent Laid-open Publication No. 10-2020-0063398 (2020.06.05.)

SUMMARY

[0015] It is an object of the present disclosure to provide an air lubrication system for ships, which can reduce frictional resistance during navigation of a ship by ejecting compressed air onto a surface of a ship bottom while ensuring high fuel efficiency, as compared with a conventional air lubrication system.

[0016] In accordance with an aspect of the present disclosure, an air lubrication system includes: at least one electrically driven compressor operated by electricity generated by a power generation engine of a ship; a steam-driven compressor driven by steam generated using exhaust gas from a main engine of the ship; an air ejector disposed at a bow of the ship and discharging compressed air supplied from the at least one

electrically driven compressor and the steam-driven compressor to an outside of the ship; and an air delivery pipe through which the compressed air supplied from the at least one electrically driven compressor and the steam-driven compressor is delivered to the air ejector; and at least one drive motor supplied with electricity generated by the power generation engine and driving the at least one electrically driven compressor, wherein the at least one electrically driven compressor comprises a first air compressor and a second air compressor disposed at the bow of the ship, and the steam-driven compressor comprises a third air compressor disposed at a stern of the ship, wherein the pressure of the compressed air generated by the first air compressor and the second air compressor is determined according to rotational speeds of a first drive motor and a second drive motor among the at least one drive motor, respectively, wherein the air delivery pipe includes a section connected to the air ejector and two sections branched off of the section and connected to the first air compressor and the second air compressor disposed at the bow of the ship, respectively, wherein a flow rate of air in the steam-driven compressor is controlled using an inlet guide vane adapted to adjust a differential pressure between a suction side and a discharge side of the steam-driven compressor for each rpm of the steam-driven compressor or using a bypass valve connected between the suction side and the discharge side, and wherein an air supply pressure of the first air compressor and the second air compressor is adjusted through a cross-sectional area adjustment device, and the cross-sectional area adjustment device is adapted to change inlet and outlet cross-sectional areas of the first air compressor, the second air compressor, and the steam-driven compressor.

[0017] The air lubrication system may further include: an exhaust gas economizer connected to the main engine and generating superheated steam through transfer of heat to saturated steam generated using the exhaust gas from the main engine; and a steam turbine having a drive shaft connected to the steam-driven compressor, the steam turbine being driven by the superheated steam generated by the exhaust gas economizer and operating the steam-driven compressor.

[0018] The air lubrication system may further include: an auxiliary boiler supplying steam to the steam turbine when the amount of steam generated by the exhaust gas economizer is insufficient.

[0019] The air lubrication system may further include: a boiler feedwater pump supplying feedwater stored in a cascade tank to the auxiliary boiler to compensate for feedwater consumed by the auxiliary boiler to generate steam.

[0020] The air lubrication system may further include: at least one steam separator receiving a fluid mixture of water and steam from the exhaust gas economizer, separating the steam from the fluid mixture, and discharging only the steam, wherein the exhaust gas economizer generates the superheated steam using the steam supplied from the at least one steam separator.

[0021] The air lubrication system may further include: a vacuum condenser condensing steam at a reduced temperature through creation of a vacuum to increase efficiency of the steam turbine; and a condensate pump delivering condensed water generated by the vacuum condenser to the cascade tank.

[0022] The air lubrication system may further include: an atmospheric condenser condensing steam generated by at least one of the exhaust gas economizer and the auxiliary boiler and supplying water condensed from the steam to the cascade tank.

[0023] The steam-driven compressor may include a gearbox therein to be operated at a constant rpm or at a variable rpm.

[0024] The air lubrication system may further include: at least one drive motor supplied with electricity generated by the power generation engine and driving the at least one electrically driven compressor.

[0025] The at least one electrically driven compressor may include a first air compressor and a second air compressor disposed at the bow of the ship, and the steam-driven compressor may include a third air compressor disposed at a stern of the ship.

[0026] The air lubrication system for ships according to the present disclosure includes the third air compressor additionally disposed at the stern of the hull, connected to the steam turbine, and generating compressed air by being driven by the steam turbine driven by steam generated using waste heat of exhaust gas from the main engine, thereby significantly reducing power consumption thereof.

[0027] In addition, the air lubrication system according to the present disclosure can provide fuel saving benefits through constant supply of compressed air regardless of ship speed.

[0028] Further, the air lubrication system according to the present disclosure can ensure redundancy through additional supply of steam from the auxiliary boiler to the steam turbine.

DRAWINGS

[0029] The above and other aspects, features, and advantages of the present invention will become apparent from the detailed description of the following embodiments in conjunction with the accompanying drawings:

[0030] FIG. 1 is a diagram of a conventional air lubrication system.

[0031] FIG. 2 is a diagram of an air lubrication system for ships according to an embodiment of the present invention.

[0032] FIG. 3 is a diagram illustrating a process of driving an air compressor using exhaust gas in the air lubrication system for ships according to the embodiment of the present invention.

DETAILED DESCRIPTION

[0033] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. Description of known functions and constructions which may unnecessarily obscure the subject matter of the present invention will be omitted.

[0034] In addition, when a certain component is referred to as being "on," "connected to," "supported by," or "coupled to" another component, it may be directly formed on, connected to, supported by, or coupled to the other component, or intervening component(s) may also be "interposed" therebetween. Further, when a fluid is referred to as being "supplied to," or "delivered to" a certain component, it may be directly supplied to or delivered to the component, or may be supplied to or delivered to the component through intervening component(s).

[0035] Although specific terms are employed herein, they are used and are to be interpreted in a descriptive sense only and not for purposes of limitation. As used herein, the singular forms, "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0036] In addition, spatially relative terms, such as "beneath," "below," "above," "upper," "right," "left," and the like, are based on depiction in the drawings and may be expressed differently when the orientation of a corresponding object is changed. For the same reason, some components are exaggerated, omitted, or schematically illustrated in the drawings and the depicted size of each component may not necessarily reflect the actual size thereof.

[0037] It should be understood that, although the terms "first," "second," and the like may be used herein to describe various components, these components should not be limited by these terms. These terms are only used to distinguish one component from another element.

[0038] Further, the terms "comprises," "comprising," "includes," and/or "including," as used herein, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, and/or components.

[0039] FIG. 2 is a diagram of an air lubrication system for ships according to an embodiment of the present invention, and FIG. 3 is a diagram illustrating a process of driving an air compressor using exhaust gas in the air lubrication system for ships according to the embodiment of the present invention.

[0040] Referring to FIG. 2, an air lubrication system 100 according to this embodiment is adapted to eject air generated by two air compressors disposed at a bow of a hull 200 and an additional air compressor disposed at a stern of the hull 200 to an outside of the hull 200 through an air injector 110.

[0041] For convenience of description, the air compressors disposed at the bow of the hull 200 will be referred to as a first air compressor 120 and a second air compressor 130, respectively, and the air compressor disposed at the stern of the hull 200 will be referred to as a third air compressor 150.

[0042] The air lubrication system 100 according to this embodiment includes the air ejector 110, the first air compressor 120, the second air compressor 130, a distribution board 140, and the third air compressor 150.

[0043] Here, the air compressors 120, 130 disposed at the bow of the hull 200 may be an electrically driven compressor, and the air compressor 150 disposed at the stern of the hull 200 may be a steam-driven compressor.

[0044] That is, unlike conventional air lubrication systems, the air lubrication system for ships according to this embodiment may include a steam-driven compressor, besides at least one electrically driven compressor which is operated by electricity generated by a power generation engine (GE) of a ship.

[0045] Although the present invention will be described with reference to an example in which two air compressors are disposed at the bow of the hull 200 and one air compressor is disposed at the stern of the hull 200, it should be understood that the present invention is not limited thereto and the number of air compressors may be varied as needed.

[0046] By way of example, at least one air compressor may be disposed at the bow in consideration of the size of the ship or the capacity of an air compressor used and the number of air compressors disposed at the stern is preferably determined in consideration of the amount of steam generated or the number of steam turbines ST.

[0047] The air ejector 110 discharges air generated by the first air compressor 120, the second air compressor 130, and the third air compressor 150 to the outside of the hull 200. The air ejector 110 may be disposed at the bow of the hull 200. The air ejector 110 may be provided with a device regulating the amount of air ejected through the air ejector 110.

[0048] The air ejector 110 may be provided with an emergency stop valve 170 to stop delivery of air to the air ejector 110 in an emergency. The emergency stop valve 170 may block discharge of air to the outside of the hull 200 when the air ejector 110 fails to normally discharge air due to, for example, abnormal pressure of air delivered through the air delivery pipe AP.

[0049] The first air compressor 120 and the second air compressor 130 are disposed at the bow of the hull 200 and supply air generated thereby to the air ejector 110. Here, the first air compressor 120 and the second air compressor 130 are driven by a first drive motor 122 and a second drive motor 132, respectively. The air generated by the first air compressor 120 and the second air compressor 130 may be supplied to the air delivery pipe AP, and the first drive motor 122 and the second drive motor 132 may be driven by electricity supplied through the distribution board 140.

[0050] The first drive motor 122 and the second drive motor 132 are driven by electricity generated by a power generation engine GE. To this end, the power generation engine GE may be provided with a switchboard SB adapted to supply electricity generated by the power generation engine GE to external devices. That is, electricity generated by the power generation engine GE may be supplied to the first drive motor 122 and the second drive motor 132 through the switchboard SB and the distribution board 140. Since the power generation engine GE and the switchboard SB are disposed at the stern of the hull 200, the switch board SB and the distribution board 140 may be electrically connected to each other through a power cable extending from the stern of the hull 200 to the bow of the hull 200.

[0051] In this embodiment, the first air compressor 120 and the second air compressor 130 may be provided in the form of a centrifugal compressor, a screw-type compressor, or a positive displacement compressor.

[0052] In addition, each of the first air compressor 120 and the second air compressor 130 may be provided at both inlet and outlet sides thereof with a cross-sectional area adjustment device (not shown), such as a guide vane, which is adapted to change inlet and outlet cross-sectional areas of the air compressor.

[0053] Alternatively, each of the first air compressor 120 and the second air compressor 130 may be provided with a device adapted to adjust internal rpm thereof.

[0054] The third air compressor 150 is disposed at the stern and may be operated using exhaust gas from the main engine ME. That is, steam generated using waste heat of the exhaust gas from the main engine ME drives a steam turbine ST, which, in turn, drives the third air compressor 150 connected to a drive shaft of the steam turbine ST. In this way, the third air compressor 150 can generate air to be supplied to the air ejector 110.

[0055] Referring to FIG. 3, in order to drive the third air compressor 150, the air lubrication system 100 may further include an exhaust gas economizer EGE, an auxiliary boiler ABL, the steam turbine ST, a boiler feedwater pump BP, an atmospheric condenser AMC, a steam separator SS, and a vacuum condenser VC.

[0056] The exhaust gas economizer EGE may be disposed on an exhaust gas pipe of the main engine ME downstream of a turbocharger TC. The exhaust gas economizer (EGE) includes an evaporating section and a superheating section. The evaporating section transfers heat from the exhaust gas to boiler water, and the superheating section transfers heat to saturated steam generated using the exhaust gas to generate superheated steam. Here, the superheating section may be located upstream of the exhaust gas economizer EGE.

[0057] The auxiliary boiler ABL may supply steam to the steam turbine ST and other devices (for example, a heater) inside the hull, which require steam. In addition, the auxiliary boiler ABL may supply steam to devices requiring steam when the amount of steam generated by the exhaust gas economizer EGE is insufficient due to a low load of the main engine ME.

[0058] In addition, the auxiliary boiler ABL may be divided into a water section and a steam separation section. The steam separation section may have a vapor space appropriately defined to discharge only vapor from boiled water to an outside of the steam separation section while preventing water from being discharged through a pipe. Here, in

order to maintain the vapor space, the boiler feedwater pump BP may control supply of feedwater to the auxiliary boiler ABL.

[0059] The boiler feedwater pump BP compensates for boiler water consumed by the auxiliary boiler ABL to generate steam. The boiler feedwater pump BP may be supplied with water from a cascade tank CT.

[0060] The atmospheric condenser AMC cools water condensed from steam used in each device and condenses surplus steam generated by the exhaust gas economizer EGE. In addition, the atmospheric condenser AMC may be supplied with coolant for condensation of the surplus steam and cooling of the condensed water.

[0061] Here, condensed water generated by the atmospheric condenser (AMC) may be transferred by gravity to the cascade tank CT. In addition, the atmospheric condenser AMC may be operated at atmospheric pressure.

[0062] Although the air lubrication system includes one steam separator SS in this embodiment, it should be understood that the present invention is not limited thereto and the air lubrication system may include two steam separators SS, as needed. The steam separator SS receives a fluid mixture of steam and water introduced into the exhaust gas economizer EGE through a circulation pump CP and having been heated, separates the steam from the fluid mixture, and discharges only the steam. The steam separator SS may have a vapor space appropriately defined to facilitate separation between the steam and the water.

[0063] Here, the steam separator SS may regulate a flow rate of water into the steam separator SS through an economizer feedwater pump EP to maintain the vapor space. In addition, the water having passed through the economizer compensation pump EP may be cooled by an air cooler AC.

[0064] An outlet of the steam separator SS may be connected to the superheating section of the exhaust gas economizer EGE.

[0065] Superheated steam may be generated by allowing saturated steam discharged from the steam separator SS to pass through the superheating section of the exhaust gas economizer EGE. The superheated steam from the exhaust gas economizer EGE is supplied to the steam turbine ST.

[0066] The superheated steam is not cooled enough to be condensed into water during transfer, thereby preventing damage to the steam turbine ST.

[0067] The steam turbine ST receives the superheated steam, expands the superheated steam from a high temperature and high pressure to a low temperature and low pressure, and converts enthalpy change obtained through this process into rotational energy.

[0068] The air lubrication may further include a governor valve GV. The governor valve GV controls a load of the steam turbine ST by regulating the amount of steam introduced into the steam turbine ST.

[0069] The air lubrication may further include a pressure valve (constant pressure valve, PV). The pressure valve is adapted to discharge surplus steam to the vacuum condenser VC to maintain a constant steam pressure such that the governor valve GV can have a constant response.

[0070] The air lubrication may further include a water spray disposed downstream of the pressure valve PV to cool the superheated steam to protect a tube and the like inside the vacuum condenser VC.

[0071] The vacuum condenser VC is adapted to increase efficiency of the steam turbine ST. The vacuum condenser VC may be provided with an air ejector or a vacuum pump to create a vacuum.

[0072] The vacuum condenser VC may create a vacuum of about -710 mmHg. Under this vacuum condition, steam is condensed at a temperature of 35°C to 37°C. That is, the vacuum condenser VC reduces a condensation temperature, above which steam remains in a vapor phase, thereby increasing enthalpy change obtainable per unit weight of the steam.

[0073] The vacuum condenser VC may be provided with a device regulating a water level in the vacuum condenser and a condensate pump CDP delivering condensed water to the cascade tank CT.

[0074] In this embodiment, the third air compressor 150 connected to at least one steam turbine ST may be operated at an rpm appropriately reduced through a gearbox. Here, the third air compressor 150 may be operated at a constant rpm or at a variable rpm.

[0075] A flow rate of air in the third air compressor 150 may be controlled using an inlet guide vane IVG adapted to adjust a differential pressure between a suction side and a discharge side of the third air compressor for each rpm or using a bypass valve connected between the suction side and the discharge side.

[0076] The air delivery pipe AP is adapted to deliver compressed air generated by the first air compressor 120 and the second air compressor 130 to the air ejector 110. In addition, the air delivery pipe AP is adapted to deliver compressed air generated by the third air compressor 150 to the air ejector 110. To this end, the air delivery pipe AP may include a section connected to the air ejector 110 and two sections branched off of the section and connected to the first air compressor 120 and the second air compressor 130 disposed at the bow of the hull 200, respectively.

[0077] In addition, the air delivery pipe AP may include a section extending from the third air compressor 150 at the stern of the hull 200, joined with the two sections extending from the first air compressor 120 and the second air compressor 130, and connected to the section connected to the air ejector 110.

[0078] The air lubrication system 100 according to this embodiment may eject air at an air ejection rate determined according to ship speed.

[0079] To this end, a pressure of compressed air generated by the first air compressor 120 and the second air compressor 130 may be determined according to a required air ejection rate.

[0080] Accordingly, the pressure of the compressed air generated by the first air compressor 120 and the second air compressor 130 may be determined according to rotational speeds of the first drive motor 122 and the second drive motor 132, respectively. In addition, a pressure of compressed air generated by the third air compressor 150 may be adjusted by regulating the amount of steam generated using exhaust gas from the main engine ME.

[0081] When the main engine ME has a low load, the third air compressor 150 may be operated using steam additionally supplied from the auxiliary boiler ABL.

[0082] In addition, an air supply pressure of the first air compressor 120 and the second air compressor 130 may be adjusted using the cross-sectional area adjustment

device adapted to change the inlet and outlet cross-sectional areas of the first air compressor 120, the second air compressor 130, and the third air compressor 150.

[0083] As described above, the air lubrication system for ships according to the embodiment of the present invention includes the third air compressor 150 additionally disposed at the stern of the hull 200, connected to the steam turbine ST, and generating compressed air by being driven by the steam turbine ST driven by steam generated using waste heat of exhaust gas from the main engine, thereby significantly reducing power consumption thereof.

[0084] In addition, the air lubrication system for ships according to the embodiment can provide fuel savings through constant supply of compressed air regardless of ship speed.

[0085] Further, the air lubrication system for ships according to the embodiment can ensure redundancy through additional supply of steam from the auxiliary boiler to the steam turbine.

[0086] Although some embodiments have been described herein, it should be understood that the foregoing embodiments are provided for illustration only and are not to be in any way construed as limiting the present invention. Therefore, the scope of the present invention should be defined by the appended claims and equivalents thereto.

[0087]

[0088] <List of Reference numerals>

100: Air lubrication system	110: Air ejector
120: First air compressor	122: First drive motor
130: Second air compressor	132: Second drive motor
140: Distribution board	150: Third air compressor
200: Hull	
ABL: Auxiliary boiler	AC: Air cooler
AMC: Atmospheric condenser	AP: Air delivery pipe
BP: Boiler feedwater pump	CDP: Condensate pump
CP: Circulation pump	CT: Cascade tank
EGE: Exhaust gas economizer	EP: Economizer feedwater pump
GE: Power generation engine	GV: Governor valve

IVG: Inlet guide vane

PV: Pressure valve

SS: Steam separator

TC: Turbocharger

ME: Main engine

SB: Switchboard

ST: Steam turbine

VC: Vacuum condenser

What is claimed is:

1. An air lubrication system comprising:
 - at least one electrically driven compressor operated by electricity generated by a power generation engine of a ship;
 - a steam-driven compressor driven by steam generated using exhaust gas from a main engine of the ship;
 - an air ejector disposed at a bow of the ship and discharging compressed air supplied from the at least one electrically driven compressor and the steam-driven compressor to an outside of the ship; and
 - an air delivery pipe through which the compressed air supplied from the at least one electrically driven compressor and the steam-driven compressor is delivered to the air ejector; and
 - at least one drive motor supplied with electricity generated by the power generation engine and driving the at least one electrically driven compressor,
 - wherein the at least one electrically driven compressor comprises a first air compressor and a second air compressor disposed at the bow of the ship, and the steam-driven compressor comprises a third air compressor disposed at a stern of the ship,
 - wherein the pressure of the compressed air generated by the first air compressor and the second air compressor is determined according to rotational speeds of a first drive motor and a second drive motor among the at least one drive motor, respectively,
 - wherein the air delivery pipe includes a section connected to the air ejector and two sections branched off of the section and connected to the first air compressor and the second air compressor disposed at the bow of the ship, respectively,
 - wherein a flow rate of air in the steam-driven compressor is controlled using an inlet guide vane adapted to adjust a differential pressure between a suction side and a discharge side of the steam-driven compressor for each rpm of the steam-driven compressor or using a bypass valve connected between the suction side and the discharge side, and
 - wherein an air supply pressure of the first air compressor and the second air compressor is adjusted through a cross-sectional area adjustment device, and the cross-

sectional area adjustment device is adapted to change inlet and outlet cross-sectional areas of the first air compressor, the second air compressor, and the steam-driven compressor.

2. The air lubrication system according to claim 1, further comprising:

an exhaust gas economizer connected to the main engine and generating superheated steam through transfer of heat to saturated steam generated using the exhaust gas from the main engine; and

a steam turbine having a drive shaft connected to the steam-driven compressor, the steam turbine being driven by the superheated steam generated by the exhaust gas economizer and operating the steam-driven compressor.

3. The air lubrication system according to claim 2, further comprising:

an auxiliary boiler supplying steam to the steam turbine when the amount of steam generated by the exhaust gas economizer is insufficient.

4. The air lubrication system according to claim 3, further comprising:

a boiler feedwater pump supplying feedwater stored in a cascade tank to the auxiliary boiler to compensate for feedwater consumed by the auxiliary boiler to generate steam.

5. The air lubrication system according to claim 4, further comprising:

at least one steam separator receiving a fluid mixture of water and steam from the exhaust gas economizer, separating the steam from the fluid mixture, and discharging only the steam,

wherein the exhaust gas economizer generates the superheated steam using the steam supplied from the at least one steam separator.

6. The air lubrication system according to claim 2, further comprising:

a vacuum condenser condensing steam at a reduced temperature through creation of a vacuum to increase efficiency of the steam turbine; and

a condensate pump delivering condensed water generated by the vacuum condenser to a cascade tank.

7. The air lubrication system according to claim 3, further comprising:

an atmospheric condenser condensing steam generated by at least one of the exhaust gas economizer and the auxiliary boiler and supplying water condensed from the steam to a cascade tank.

8. The air lubrication system according to claim 1, wherein the steam-driven compressor comprises a gearbox therein to be operated at a constant rpm or at a variable rpm.