DESCRIPTION

TITLE OF THE INVENTION: CARBON DIOXIDE REDUCTION DEVICE USING STEAM PLASMA

CROSS-REFERENCE TO RELATED PATENT APPLICATION

The present application claims priority under 35 U.S.C. § 119(a) to Korean patent application number 10-2025-0028193 filed on March 5, 2025, in the Korean Intellectual Property Office, the entire disclosure of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field

Embodiments of the present disclosure relate to a carbon dioxide reduction device for removing carbon dioxide contained in exhaust gas of a ship engine, and more specifically, to a carbon dioxide reduction device using steam plasma, which is coupled to an inlet pipe or an outlet pipe of a scrubber that captures harmful substances in the exhaust gas, and sprays steam plasma mixed with a catalyst into the exhaust gas passing through the inside of the inlet pipe or the outlet pipe, thereby effectively capturing and removing carbon dioxide contained in the exhaust gas.

2. Description of the Related Art

In general, ships are equipped and operated with a main engine that drives a propeller for propelling the ship, and a number of power generation engines for supplying power to various equipment or operating facilities mounted on the ship.

These ship engines are typically operated using marine diesel oil (MDO) or heavy fuel oil (HFO) such as bunker C oil, and function as propulsion engines that propel heavy hulls or power generation engines that require large-capacity power generation.

However, the exhaust gas emitted after combustion from MDO of a ship contains not only a large number of suspended particulates such as dust and fine dust, but also a large number of harmful substances such as nitrogen oxides (NOx), sulfur oxides (SOx), and carbon dioxide (CO_2), which has become a cause of environmental pollution.

In order to reduce the emission of these environmental pollutants, countries around the world are regulating the amount of emissions through environmental regulations, and the International Maritime Organization (IMO) is also strengthening the regulations on the emission of harmful substances not only in ports but also on the high seas, and through this, ships sailing across all oceans around the world are being regulated to reduce the sulfur content of their fuel oil from the existing 3.5% or less to 0.5% or less, and total carbon dioxide emissions regulations are being promoted to reduce carbon emissions from ships by 100% by 2050 compared to 2008 levels.

Moreover, from January 1, 2023, the Energy Efficiency Existing Ship Index (EEXI) regulation and the Carbon Intensity Indicator (CII) regulation which is an operational measure, are being implemented to regulate greenhouse gas emissions.

Accordingly, each shipping company is using expensive low-sulfur fuel oil or LNG, or installing and operating scrubber (SOx removal) devices or the like to reduce sulfur oxides in the engine exhaust line as a type of harmful substance collection device, and is promoting the integration of technologies such as carbon capture and storage (CCS) or carbon capture utilization storage (CCUS) into ships as carbon capture technologies to respond to total carbon dioxide emissions regulations in exhaust gas.

However, the conventional methods for reducing environmental pollutants as described above had the following problems.

First, in the case of using expensive low-sulfur oil or LNG fuel as fuel for ship engines, although it is possible to reduce the emission of environmental pollutants compared to diesel fuel, there was a problem that the cost of maritime logistics increases significantly as the ship's fuel cost increases.

Second, in the case of scrubbers that reduce sulfur oxides in exhaust gas, although it is possible to remove sulfur oxides, dust, or fine dust contained in exhaust gas, there was a problem that the greenhouse gases such as carbon dioxide cannot be removed.

Third, in the case of carbon capture technologies such as CCS or CCUS that may be used to remove carbon dioxide, there was a problem that the relatively large volume and heavy weight reduce the deadweight tonnage (DWT) of the ship, thereby causing significant operational losses in ship operation and cargo transportation.

SUMMARY OF THE INVENTION

The present disclosure has been devised to solve the problems described above, and an object of the present disclosure is to enable the removal of sulfur oxides, fine dust, and the like in exhaust gas as well as carbon dioxide by coupling a carbon dioxide reduction device to a scrubber installed on a ship and operating in an integrated manner together with the scrubber.

Another object of the present disclosure is to enable the effective removal of carbon dioxide by directly discharging plasma in which a catalyst and high-temperature steam are mixed into the exhaust gas, thereby increasing the reactivity of the catalyst material with carbon dioxide.

Still another object of the present disclosure is to enable more effective reduction of carbon by ionizing the catalyst through steam plasma and spraying it into the exhaust gas line, thereby activating ionic bonds with carbon dioxide in the exhaust gas.

Still another object of the present disclosure is to maximize energy efficiency by minimizing power consumption compared to existing methods by using plasma.

Yet another object of the present disclosure is to enable reduction of not only SOx but also CO_2 in exhaust gas by installing a carbon dioxide reduction device in a modular manner when installing a scrubber on an existing ship.

In order to achieve the above described objects, an embodiment may provide a carbon dioxide reduction device using steam plasma, wherein at least one carbon dioxide reduction device is coupled to at least any one side of an inlet pipe or an outlet pipe of a scrubber through which exhaust gas passes to remove carbon dioxide in the exhaust gas, the carbon dioxide reduction device including a plasma catalyst spray module provided with a plasma head having a front end part which penetrates and is coupled to an outer circumferential surface of the inlet pipe or the outlet pipe of the scrubber to discharge plasma from a lateral side of the exhaust gas passing through the inlet pipe or the outlet pipe, an electromagnetic wave generator coupled to an outer circumferential surface of the plasma head to transmit electromagnetic waves to the plasma emitted within the plasma head, a catalyst injector coupled to the outer circumferential surface of the plasma head to spray a catalyst which removes carbon dioxide contained in the exhaust gas to the plasma, and a steam supplier coupled to the outer circumferential surface of the plasma head to spray high-temperature steam from a lateral side to the plasma to form steam plasma.

Here, the plasma head includes a plasma torch configured to generate and discharge the plasma, and a discharge guide pipe of a hollow structure having a front end part coupled to

the inlet pipe or the outlet pipe and a rear end part coupled to a front end part of the plasma torch to guide the plasma.

In addition, it is preferable that a plurality of plasma heads are installed radially at predetermined intervals along the outer circumferential surface of the inlet pipe or the outlet pipe and the plasma is discharged toward an inner center point of the inlet pipe or the outlet pipe.

In addition, a plurality of plasma heads may be installed at predetermined intervals along the outer circumferential surface of the inlet pipe or the outlet pipe, and installed to be inclined in a radial direction of the inlet pipe or the outlet pipe so that the plasma is discharged toward between an inner center point and an inner circumferential surface of the inlet pipe or the outlet pipe to be movable while rotating along the inner circumferential surface of the inlet pipe or the outlet pipe.

In addition, the plasma head may be installed to be inclined in a longitudinal direction of the inlet pipe or the outlet pipe so that the plasma is discharged inclined at a predetermined angle toward a proceeding direction of the exhaust gas.

It is preferable that the catalyst injector is provided with a catalyst supply pipe coupled to an outer circumferential surface of the discharge guide pipe, wherein the catalyst supply pipe is installed so as to spray the catalyst from the lateral side of the plasma by being coupled between a location where the electromagnetic wave is transmitted to the plasma and a plasma nozzle from which the plasma is emitted.

In addition, it is preferable that the steam supplier is provided with a steam supply pipe coupled to the outer circumferential surface of the discharge guide pipe, wherein the steam supply pipe is installed between the catalyst supply pipe and the plasma nozzle.

In addition, the catalyst injector may use sodium hydroxide (NaOH) or potassium hydroxide (KOH) as a catalyst.

As described above, the present disclosure has the following effects.

The present disclosure has the effect of satisfying the IMO's total carbon dioxide emissions regulations by being able to remove not only sulfur oxides, fine dust, and the like in exhaust gas, but also carbon dioxide.

In addition, the present disclosure has the effect of more reliably removing carbon dioxide by being able to increase the reactivity between the catalyst material and carbon dioxide by applying plasma containing the catalyst material and steam.

In addition, the present disclosure has the effect of uniformly reducing the concentration of carbon dioxide in exhaust gas by inducing uniform diffusion of the catalyst material through uniformizing the overall temperature distribution of plasma using high-temperature steam, and also securing temperature uniformity of the entire equipment, thereby delaying the aging of the equipment.

In addition, the present disclosure has the effect of improving the utilization of installation space by being attachable to and detachable from a scrubber, and significantly reducing installation costs by minimizing unnecessary facility construction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a configuration explanatory diagram of a carbon dioxide reduction device using steam plasma of the present disclosure.

FIG. 2 is a configuration diagram of a plasma head provided in a plasma catalyst spray module of the present disclosure.

FIG. 3 is a plan view and a perspective view of a state in which a carbon dioxide reduction device of the present disclosure is installed in a scrubber.

FIG. 4 is a plan view and a perspective view of another embodiment in which a carbon dioxide reduction device of the present disclosure is installed in a scrubber.

FIG. 5 is a perspective view of an embodiment in which a carbon dioxide reduction device of the present disclosure is installed in an inlet pipe of a scrubber.

FIG. 6 is a front view of the embodiment of FIG. 5.

FIG. 7 is a plan layout view of various embodiments in which a plasma head of a carbon dioxide reduction device of the present disclosure is installed.

FIG. 8 is an explanatory diagram of another embodiment in which a plasma head of a carbon dioxide reduction device of the present disclosure is installed.

DETAILED DESCRIPTION

Hereinafter, a carbon dioxide reduction device using steam plasma of the present disclosure will be described in detail with reference to the drawings.

First, the entire configuration of the present disclosure will be described based on FIGS. 1 and 2.

Here, FIG. 1 is a configuration explanatory diagram of a carbon dioxide reduction device using steam plasma of the present disclosure, and FIG. 2 is a configuration diagram of a plasma head provided in a plasma catalyst spray module of the present disclosure.

Here, FIG. 2 illustrates a plasma head 20 provided in a plasma catalyst spray module 10, and plasma 200 is simply illustrated in an oval shape for convenience of explanation.

The carbon dioxide reduction device using steam plasma of the present disclosure is used by being coupled to a scrubber 100, and removes carbon dioxide (carbon) in the exhaust gas by spraying plasma 200, in which a catalyst and high-temperature steam are mixed, into the exhaust gas passing through the scrubber 100.

First, the scrubber 100 will be briefly described.

The scrubber 100 is connected to the exhaust line of a ship engine to remove harmful substances in exhaust gas, and is a device that purifies exhaust gas by capturing and removing

not only gaseous substances such as sulfur oxides (SOx) but also suspended particulates, such as dust or fine dust, in the exhaust gas through contact and coagulation of gas and liquid.

Accordingly, the scrubber 100 is formed as a rectangular housing structure with a hollow inside so that exhaust gas may pass through, and at this time, an inlet pipe 120 and an outlet pipe 130 (see FIG. 3) through which exhaust gas may be introduced and discharged are respectively provided on the side surface and upper side surface of the main body of the scrubber 100.

In addition, a seawater supply pipe 110 (see FIG. 3) is installed on the outer circumferential surface of the scrubber 100 to adsorb and remove sulfur oxides, dust, and the like in the exhaust gas by spraying seawater multiple times through a plurality of nozzles onto the exhaust gas passing through the inside.

Accordingly, the exhaust gas enters the inside of the main body through the inlet pipe 120 of the scrubber 100, and after harmful substances are removed by seawater sprayed through the nozzle, the exhaust gas is discharged to the outside through the outlet pipe 130.

The carbon dioxide reduction device using steam plasma of the present disclosure is coupled to at least any one side of the inlet pipe 120 or the outlet pipe 130 of the scrubber 100, and is configured to include a plasma catalyst spray module 10, an electromagnetic wave generator 50, a catalyst injector 70, and a steam supplier 80, as illustrated in FIG. 1.

The plasma catalyst spray module 10 includes a plasma head 20 that generates and discharges plasma 200 (illustrated in FIG. 2) and a sub-unit 30.

Here, the sub-unit (30) consists of a controller 31, a power supplier 33, and a gas supplier 35.

The plasma head 20 has a front end part connected to the outer circumferential surface of the inlet pipe 120 or the outlet pipe 130 of the scrubber 100, and discharges plasma 200 into the exhaust gas passing through the inside of the inlet pipe 120 or the outlet pipe 130.

Meanwhile, the power supplier 33 of the sub-unit 30 supplies power to the plasma head 20 through a power cable 34, and the gas supplier 35 supplies a process gas to be plasma-activated to the plasma head 20 through a gas supply pipe 36.

Here, the power supplier 33 supplies power such as direct current, alternating current, and high frequency (RF) to a pair of electrodes provided in the plasma head 20 to generate an arc discharge, thereby generating plasma 200.

Meanwhile, the controller 31 controls the power supplier 33 and the gas supplier 35 through a conventional control circuit, and adjusts the voltage applied to the electrode in the plasma head 20 by the power supplier 33, and also controls the amount of process gas supplied by the gas supplier 35.

The plasma head 20, as illustrated in FIG. 2, generates plasma 200 under atmospheric pressure and discharges the plasma 200 to the object to be treated (exhaust gas), and includes a plasma torch 22 and a discharge guide pipe 25.

The plasma torch 22 has a negative electrode (not shown) that emits electrons and a positive electrode that also serves as a plasma nozzle 23 that emits plasma 200, and a reaction chamber (not shown) that generates plasma 200 by arc discharge between the negative and positive electrodes is formed therein.

Accordingly, when the process gas supplied through the gas supply pipe 36 is injected into the reaction chamber, the plasma torch 22 generates a jet plasma through arc discharge within the reaction chamber, thereby emitting plasma 200 through the plasma nozzle 23.

Here, typical plasma treatment gases such as oxygen, helium, argon, and nitrogen may be used as the process gas.

Here, the generated plasma 200 has a central temperature of approximately 10,000 to 20,000°C, and an external temperature of 3,000 to 4,000°C.

The plasma torch 22 is not particularly limited in its structure as long as it generates plasma 200 by an arc discharge between a general negative electrode and a positive electrode, and emits the plasma 200 forward through a nozzle.

The discharge guide pipe 25 is formed as a hollow structure in the shape of a cylinder with an empty interior, so that the plasma 200 emitted from the plasma torch 22 is discharged into the inlet pipe 120 or the outlet pipe 130 of the scrubber 100.

Here, the discharge guide pipe 25 has a front end part penetrating and coupled to the outer circumferential surface of the inlet pipe 120 or the outlet pipe 130, and a rear end part coupled to the front end part of the plasma torch 22.

In addition, the front end part of the discharge guide pipe 25 may be provided with a flange 26 capable of connecting a waveguide 52 of the electromagnetic wave generator 50 described below, and a flange 27 capable of connecting to the inlet pipe 120 or the outlet pipe 130.

The flange 26, 27 may be appropriately modified and applied depending on the size and structure of the inlet pipe 120 or the outlet pipe 130, the structure of the waveguide 52, etc., and, if necessary, a separate connecting member (not shown) may be added.

Accordingly, as illustrated in FIG. 2, the plasma 200 emitted from the plasma torch 22 moves along the discharge guide pipe 25 and is then discharged into the exhaust gas inside the inlet pipe 120 or outlet pipe 130 of the scrubber 100.

Meanwhile, the electromagnetic wave generator 50 directly adds electromagnetic waves to the plasma 200 emitted from the plasma torch 22, and as illustrated in FIGS. 3 and 5, may be installed on the upper side surface or the side surface of the scrubber 100 along the circumference of the inlet pipe 120 or the outlet pipe 130 of the scrubber 100, and at this time, the waveguide 52 that transmits the electromagnetic waves is connected to the discharge guide

pipe 25 of the plasma head 20 and communicates with the inside of the discharge guide pipe 25.

As illustrated in FIG. 3, four electromagnetic wave generators 50 may be installed along the circumference of the outlet pipe 130, but the present disclosure is not limited thereto, and one or more may be installed at predetermined intervals.

Here, a conventional magnetron that generates electromagnetic waves in the band of approximately 10 MHz to 10 GHz may be used as the electromagnetic wave generator 50, so a detailed description thereof is omitted here.

The electromagnetic wave generator 50, as illustrated in FIG. 2, transmits the electromagnetic wave generated from the magnetron to the plasma 200 through the waveguide 52 connected to the discharge guide pipe 25 of the plasma head 20.

Therefore, the waveguide 52, as illustrated in FIG. 2, may be installed so as to communicate with the inside of the discharge guide pipe 25 by having a front end part coupled to penetrate a lateral side of a connecting flange 55 for connecting to the flange 26 of the discharge guide pipe 25.

The connecting flange 55 is formed as a hollow structure so that the plasma 200 may pass through and is coupled to the flange 26 of the discharge guide pipe 25, and at this time, it is preferable that a sealing member, such as packing, be installed at the connection part of the discharge guide pipe 25 and the waveguide 52 to maintain airtightness.

The waveguide 52 is connected from the lateral side of the plasma head 20 and is coupled to communicate with the internal space of the discharge guide pipe 25, so as to transmit electromagnetic waves to the plasma 200 in a vertical direction from the lateral side of the plasma 200.

In addition, the waveguide 52, as illustrated in FIG. 2, may be formed into a tubular structure having a cross-section of approximately square or rectangular shape with a

predetermined width and height, or a cylindrical structure, and it is preferable that the front end part connected to the connecting flange 55 has an inclined surface 54 formed on one side surface.

The wavelength of the electromagnetic wave transmitted from the electromagnetic wave generator 50 may be determined according to the specifications such as the length and width of the waveguide 52, and the waveguide 52 may be applied by being modified in various shapes according to the shape of the plasma head 20, required emission conditions, etc., and thus is not limited to the shape illustrated in FIG. 2, and may be manufactured and applied in various specifications and shapes according to the wavelength of the electromagnetic wave required in the design, or the installation space or location, etc.

Here, it is preferable that the waveguide 52 be disposed at a location spaced a predetermined distance apart from the plasma nozzle 23 in the longitudinal direction of the plasma 200 (in the direction of plasma emission).

As an indication of the location where the waveguide 52 is coupled to the discharge guide pipe 25, the distance spaced apart from the plasma nozzle 23 in the longitudinal direction of the plasma 200 may be appropriately selected and determined by considering the wavelength of the electromagnetic wave transmitted through the waveguide 52.

Accordingly, the electromagnetic wave generator 50 transmits electromagnetic waves to the emitted plasma 200, thereby directly heating the side part of the plasma 200 and supplying thermal energy, and increasing the width and length of the plasma 200 and expanding the overall volume, thereby improving the reactivity of carbon dioxide and the catalyst, thereby enabling more effective removal of carbon dioxide.

For example, the catalyst injector 70 is connected to the discharge guide pipe 25 of the plasma head 20 as illustrated in FIGS. 1 and 2.

The catalyst injector 70 is provided with a catalyst supply pipe 72 for supplying a catalyst, and the front end of the catalyst supply pipe 72 is coupled to the outer circumferential surface of the discharge guide pipe 25 from the lateral side so as to be able to communicate.

Here, the catalyst supply pipe 72 is preferably installed so as to be connected between the location where electromagnetic waves are transmitted to the plasma 200 in the discharge guide pipe 25 and the plasma nozzle 23 from which the plasma 200 is emitted, so as to spray the catalyst from the lateral side of the plasma 200.

The catalyst injector 70 sprays the catalyst into the plasma 200 using a pump or the like from a separate catalyst storage tank (not shown).

Here, the catalyst injector 70 may have one or multiple spray nozzles installed at the front end part of the catalyst supply pipe 72 so as to spray the catalyst, and may also be operated by installing one or multiple nozzles in a modular manner as needed.

The catalyst sprayed is a strong alkaline substance that may be combined with carbon dioxide in the exhaust gas, and an aqueous solution of lithium hydroxide (LiOH), calcium hydroxide ($Ca(OH)_2$), rubidium hydroxide (RbOH), barium hydroxide ($Ba(OH)_2$), magnesium hydroxide ($Mg(OH)_2$), ammonia water (NH_4OH), sodium hydroxide (NaOH), potassium hydroxide (KOH), cesium hydroxide (CsOH), strontium hydroxide ($Sr(OH)_2$), etc., may be used.

Therefore, the catalyst supplied from the catalyst injector 70 becomes more reactive as it enters the inside of the high-temperature plasma 200, and may be effectively combined with carbon dioxide in the exhaust gas.

The steam supplier 80 is connected to the discharge guide pipe 25 of the plasma head 20 through a steam supply pipe 82 as illustrated in FIG. 2.

The steam supplier 80 may further increase the reactivity between the catalyst and carbon dioxide by spraying high-temperature steam into the plasma 200 inside the discharge

guide pipe 25 through the steam supply pipe 82, thereby adding thermal energy to the plasma 200.

Here, the steam supplier 80 may utilize a waste heat boiler (not shown) used in a ship, and may utilize high-temperature steam of about 250°C to 300°C generated from the boiler, and this steam contains water (H_2O).

Here, the steam supply pipe 82 is communicatively connected to the outer circumferential surface of the discharge guide pipe 25 between the location where the catalyst supply pipe 72 is installed and the plasma nozzle 23.

Therefore, the steam supply pipe 82 quickly adds steam thermal energy to the plasma to form steam plasma 200, and by spraying the catalyst into this steam plasma 200, the activation energy of the catalyst may be further enhanced.

In other words, the steam plasma 200 in which high-temperature steam is mixed increases the speed of the chemical reaction, thereby more effectively promoting the decomposition of pollutants in the exhaust gas.

In addition, the high-temperature steam sprayed into the plasma 200 acts as a heat transfer medium to disperse and absorb the excessive heat generated during the plasma 200 generation process, thereby inducing a uniform temperature distribution throughout the plasma 200, thereby not only enabling the catalyst to be uniformly diffused, but also ensuring temperature uniformity throughout the equipment.

Meanwhile, since the high-temperature steam may utilize those generated from waste heat boilers or the like used in ships, energy may be efficiently reused, thereby not only increasing the energy efficiency of the entire system but also reducing equipment operating costs.

In addition, high-temperature steam may induce various chemical reactions and help expand the range of treatable harmful substances, and since it has a high specific heat, when it

enters the discharge guide pipe 25 at a high temperature, it transfers a large amount of heat, so that the thermal energy of the steam is transferred to the gas molecules, increasing their kinetic energy and greatly increasing their reactivity.

Meanwhile, the plasma catalyst spray module 10, the electromagnetic wave generator 50, the catalyst injector 70, and the steam supplier 80 are connected to the main controller 150 connected to the scrubber 100, so that the plasma generation and discharge, the electromagnetic wave transmission, the catalyst supply amount and supply timing, the steam supply amount, and the like may be appropriately controlled depending on whether the engine is operating or the scrubber 100 is operating.

Here, the main controller 150 may control the carbon dioxide reduction device of the present disclosure and the scrubber 100 to be operated integrally or separately.

Hereinafter, with reference to FIGS. 3 to 6, an embodiment in which a carbon dioxide reduction device using steam plasma of the present disclosure is installed in a scrubber will be described in detail.

Here, FIG. 3 illustrates an embodiment of a state in which a carbon dioxide reduction device of the present disclosure is installed in an outlet pipe of a scrubber, wherein FIG. 3A is a plan view and FIG. 3B is a perspective view, and FIG. 4 illustrates another embodiment of a state in which a carbon dioxide reduction device of the present disclosure is installed in an outlet pipe of a scrubber, wherein FIG. 4A is a plan view and FIG. 4B is a perspective view.

In addition, FIG. 5 is a perspective view of an embodiment in which a carbon dioxide reduction device of the present disclosure is installed in an inlet pipe of a scrubber, and FIG. 6 is a front view of the embodiment of FIG. 5.

Here, FIGS. 3 to 6 omit some components for convenience of explanation where only the front end part of the plasma head 20 coupled to the scrubber 100 and the electromagnetic

wave generator 50 are illustrated, and other than these, the catalyst injector 70, steam supplier 80, and sub-unit 30 of the plasma catalyst spray module 10 are omitted.

At least one or more multiple plasma carbon dioxide reduction devices of the present disclosure are installed, and the embodiment of FIG. 3 illustrates an example in which four are installed on the upper side surface of the scrubber 100, and at this time, four plasma heads 20 are radially coupled at regular intervals along the outer circumferential surface of the outlet pipe 130.

Here, the plasma head 20 is coupled in a vertical direction from the lateral side of the outlet pipe 130 and is installed so that the discharged plasma 200 is discharged toward the inner center point of the outlet pipe 130.

The electromagnetic wave generator 50 connected to the plasma head 20 is installed on the upper side surface of the scrubber 100 at the rear on the same line as each plasma head 20, as illustrated.

The electromagnetic wave generators 50 may be installed by being fixed to the upper side surface of the scrubber 100 using separate fixing members, and may also be installed by being fixed on a separate rail so that the locations may be adjusted.

Accordingly, the plasma 200 generated from the plasma head 20 is mixed with the electromagnetic wave transmitted from the electromagnetic wave generator 50, the catalyst supplied from the catalyst injector 70, and the high-temperature steam, and then discharged on the same plane toward the center point inside the outlet pipe 130 to react with the exhaust gas.

In addition, as illustrated in FIG. 4, three carbon dioxide reduction devices of the present disclosure may be installed at regular intervals along the outer circumferential surface of the outlet pipe 130.

Here, the plasma head 20 is installed so as to be inclined at a predetermined angle in the same direction (radial direction) along the outer circumferential surface of the outlet pipe

130 when viewed from above, as illustrated in FIG. 4, so that the discharged plasma 200 may be discharged toward between the inner center point and the inner circumferential surface of the outlet pipe 130.

Accordingly, the steam plasma 200 in which the catalyst is mixed rotates counterclockwise along the inner circumferential surface of the outlet pipe 130, and by this rotational motion, a vortex or swirling motion is induced in the exhaust gas, thereby enabling a more rapid reaction.

FIGS. 5 and 6 illustrate an example in which the carbon dioxide reduction device using steam plasma of the present disclosure is installed in the inlet pipe 120 of the scrubber 100, and four of them may be installed on the outer circumferential surface of the inlet pipe 120 of the scrubber 100.

Here, two carbon dioxide reduction devices of the present disclosure may be installed so as to face each other with the inlet pipe 120 in between, by being installed on each of the left and right sides of the inlet pipe 120 along the longitudinal direction of the inlet pipe 120, as illustrated.

Accordingly, the plasma heads 20 are installed in pairs of two, spaced apart at a predetermined interval along the longitudinal direction of the inlet pipe 120.

Here, the plasma heads 20 may be installed so that one pair of the front parts (the entry part of the exhaust gas) face each other in the up-down direction, and one pair of the back parts face each other in the left-right direction of the inlet pipe 120.

In this case, when viewed from the front of the inlet pipe 120, the plasma 200 forms a form in which four plasmas 200 are discharged in the up-down, left-right directions, as illustrated in FIG. 6.

The electromagnetic wave generator 50 may be fixed to the side surface of the scrubber 100 using a separate frame member (not shown), and in addition, the waveguide 52 may be

applied by appropriately changing the shape and length corresponding to the installation location of the plasma head 20.

Accordingly, the steam plasma 200 and catalyst discharged from the plasma head 20 are discharged while being spaced apart from each other along the longitudinal direction of the inlet pipe 120, thereby being able to be mixed twice with the exhaust gas moving along the inlet pipe 120, thereby enabling more effective removal of carbon dioxide.

In addition, even when the plasma head 20 is installed in the inlet pipe 120 as in the embodiment of FIGS. 5 and 6, the plasma 200 may be disposed so as to be discharged on the same cross-section of the inlet pipe 120 as in the embodiment of FIGS. 3 and 4, or multiple numbers may be installed to be inclined at a predetermined angle in the radial direction along the outer circumferential surface of the inlet pipe 120.

In other words, one or more multiple plasma heads 20 may be installed in any one or both sides of the inlet pipe 120 or the outlet pipe 130, and the discharge direction of the plasma 200 may also be appropriately selected and applied.

The sub-unit 30 of the plasma catalyst spray module 10, the catalyst injector 70, and the steam supplier 80, which are not illustrated in FIGS. 3 to 6, may be appropriately installed around the installation space of the scrubber 100.

Hereinafter, the operation process of the carbon dioxide reduction device using steam plasma of the present disclosure will be described in detail.

First, as illustrated in FIGS. 3 and 4, the description will be based on an example in which the plasma head 20 of the plasma catalyst spray module 10 is installed in the outlet pipe 130 of the scrubber 100.

When the ship engine is started, the exhaust gas enters the scrubber 100 main body through the inlet pipe 120 of the scrubber 100 via the exhaust line.

Here, the scrubber 100 operates by determining the operating conditions of the engine and the timing and amount of seawater supply according to these conditions by the main controller 150.

Therefore, the scrubber 100 sprays seawater into the exhaust gas flowing in through the inlet pipe 120 in response to the engine starting, and the seawater adsorbs fine dust, sulfur oxides and the like contained in the exhaust gas and falls, and is then recovered through a separate seawater discharge pipe (not shown), and the exhaust gas purified of harmful substances is discharged to the outside of the scrubber 100 through the outlet pipe 130.

Here, the main controller 150 operates the plasma catalyst spray module 10, the electromagnetic wave generator 50, the catalyst injector 70, and the steam supplier 80 in response thereto.

The plasma catalyst spray module 10 supplies power to the plasma torch 22 of the plasma head 20 and simultaneously supplies the process gas to the reaction chamber within the plasma torch 22, thereby inducing an arc discharge and generating plasma 200.

Here, the plasma 200 is emitted forward from the plasma nozzle 23 along the discharge guide pipe 25.

In addition, the electromagnetic wave generator 50, the catalyst injector 70, and the steam supplier 80 also operate, thereby transmitting electromagnetic waves to the plasma 200 within the discharge guide pipe 25 and spraying the catalyst and high-temperature steam.

Here, the electromagnetic waves supply energy to the plasma 200 into which the steam is sprayed, thereby expanding the width and length of the plasma 200 to increase the overall volume of the steam plasma 200, thereby improving the contact area with the exhaust gas and enhancing the reactivity of the catalyst.

Accordingly, the catalyst sprayed into the plasma 200 is mixed with the exhaust gas in a state of high activation energy by the high-temperature steam and electromagnetic waves.

The catalyst that enters the exhaust gas together with the plasma 200 selectively combines with the carbon dioxide in the exhaust gas to remove the carbon dioxide, and the exhaust gas from which the carbon dioxide has been removed is finally discharged to the outside through the outlet pipe 130.

In addition, the volume of the plasma 200 emitted from the plasma head 20, the intensity of the electromagnetic wave transmitted from the electromagnetic wave generator 50, the amount of steam supplied and the like may be appropriately adjusted in consideration of the arrangement structure of the plasma head 20, the size of the inlet pipe 120 or the outlet pipe 130 of the scrubber 100 and the like.

In the carbon dioxide reduction device of the present disclosure, sodium hydroxide (NaOH) and potassium hydroxide (KOH) may be mainly used as the catalyst.

Here, the reaction formula of the catalyst sodium hydroxide and potassium hydroxide with carbon dioxide is as follows.

1) $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$ (produces sodium carbonate and water)

2) $2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$ (produces potassium carbonate and water)

Therefore, the catalysts, sodium hydroxide and potassium hydroxide, combine with the carbon dioxide in the exhaust gas to produce water together with sodium carbonate/potassium carbonate, respectively, thereby removing carbon dioxide.

In addition, when installed in the inlet pipe 120 of the scrubber 100, as illustrated in FIGS. 6 and 7, the carbon dioxide reduction device of the present disclosure may remove carbon dioxide before the exhaust gas enters the scrubber 100, and the reaction process of the carbon dioxide and the catalyst at this time is the same as in the example of installation in the outlet pipe 130.

In addition, by installing a carbon dioxide detection sensor in the outlet pipe 130 of the scrubber 100 and having the main controller 150 appropriately adjust the supply amount of

plasma 200, electromagnetic waves, catalyst, and steam based on the detected data, it will be possible to efficiently control the amount of electromagnetic waves emitted or the amount of catalyst and steam supplied rapidly in response to the concentration of carbon dioxide contained in the exhaust gas.

Hereinafter, examples of various arrangement structures of the plasma head 20 will be described with reference to FIG. 7.

Here, FIG. 7 is a plan layout view of various installation examples of the plasma head 20 provided in the carbon dioxide reduction device of the present disclosure, wherein FIG. 7A shows an example in which the plasma head 20 is installed vertically from the lateral side of the inlet pipe 120 or the outlet pipe 130, and FIG. 7B shows an example in which the plasma head 20 is installed to be inclined in the radial direction from the lateral side of the inlet pipe 120 or the outlet pipe 130.

In addition, FIG. 7 only illustrates the plasma head 20 for convenience of explanation.

As illustrated in FIG. 7A, one or more multiple plasma heads 20 provided in the present disclosure may be installed radially on the same plane along the outer circumferential surface of the inlet pipe 120 or the outlet pipe 30, and at this time, the plasma heads 20 are coupled from the lateral side of the inlet pipe 120 or the outlet pipe 130 in the vertical direction.

Accordingly, the plasma 200 in which steam and catalyst are mixed is discharged from the lateral side toward the center point (center point of the flow path) inside the inlet pipe 120 or the outlet pipe 130.

By doing so, not only the contact area between the plasma 200 and the exhaust gas increases, but also the reactivity of the catalyst mixed in the steam plasma 200 and the carbon dioxide in the exhaust gas may be improved.

As shown in FIG. 7B, a plurality of plasma heads 20 may be disposed in the inlet pipe 120 or the outlet pipe 130, and may be installed to be inclined at a predetermined angle in the radial direction of the inlet pipe 120 or the outlet pipe 130.

Here, it is preferable that the plasma head 20 discharge the plasma 200 toward the portion (middle portion) between the inner center point of the inlet pipe 120 or the outlet pipe 130 and the inner circumferential surface.

Accordingly, the plasma 200 in which steam and catalyst are mixed may rotate in a circle along the inner circumferential surface, thereby forming a vortex or eddy shape, and since it rotates in a spiral shape due to the flow pressure of the exhaust gas and progresses in the direction of the flow path, the contact area with the exhaust gas may be further expanded, thereby improving the reactivity between the catalyst and carbon dioxide.

Although various arrangement structures of the plasma head 20 are described in FIG. 7, it is not limited to this arrangement structure, and some plasma heads 20 may be installed as in FIG. 7A, and the remaining plasma heads 20 may be installed as in FIG. 7B, so that arrangements in which the plasma heads are disposed in the vertical direction or inclined direction from the lateral side of the inlet pipe 120 or the outlet pipe 130 may be applied in combination.

In addition, as illustrated in FIG. 5, the various installation examples of the plasma heads 20 illustrated in FIG. 7 may also be installed along the longitudinal direction of the inlet pipe 120 or the outlet pipe 130 at intervals.

In the case of installing the plurality of plasma heads 20 as illustrated in FIG. 7, the sub-unit 30 may be connected to each plasma head 20, or power and gas may be supplied to each plasma head 20 simultaneously from one sub-unit 30.

Hereinafter, the arrangement structure of another embodiment of the plasma head will be described with reference to FIG. 8.

Here, FIG. 8 illustrates another embodiment in which the plasma head 20 of the carbon dioxide reduction device of the present disclosure is installed in the inlet pipe 120 or the outlet pipe 130.

As shown in FIG. 8, the plasma head 20 coupled to the inlet pipe 120 or the outlet pipe 130 may be installed to be slightly inclined with respect to the progression direction of the exhaust gas.

The plasma head 20 may be coupled to the inlet pipe 120 or the outlet pipe 130 to be inclined through a separate connecting member 29 in consideration of the width and length of the discharged plasma 200, and at this time, it is preferable that the inclination angle A be an appropriate angle in consideration of the coupling structure and effect of the plasma head 20.

Here, it is preferable to set the inclination angle A to be approximately 30 to 80 degrees in consideration of the progression direction of the exhaust gas.

By doing so, the contact area and contact time of the plasma 200 and the exhaust gas may be increased, thereby effectively reducing the carbon dioxide concentration of the entire exhaust gas.

In addition, when the plasma 200 is discharged in the vertical direction from the lateral side of the inlet pipe 120 or the outlet pipe 130, the progression of the exhaust gas may be inhibited, so as illustrated, the plasma head 20 is installed to be inclined toward the progression direction of the exhaust gas (arrow direction), thereby preventing the back pressure from being applied to the flow of the exhaust gas, thereby preventing the load on the engine from increasing or the output from decreasing.

As in the case of the plasma head 20 illustrated in FIG. 8, the waveguide 52, the catalyst supply pipe 72, and the steam supply pipe 82 may be installed to be inclined at a predetermined angle in the longitudinal direction of the discharge guide pipe 25 so that the electromagnetic waves, catalyst, and steam may be supplied in an inclined manner toward the

emission direction of the plasma 200, thereby increasing the contact area and contact time with the plasma 200 to enable rapid diffusion.

As described above, the carbon dioxide reduction device using steam plasma 200 of the present disclosure may effectively respond to environmental regulations on exhaust gas of a ship engine by not only removing sulfur oxides, fine dust, and the like in exhaust gas through the scrubber 100, but also discharging catalyst-containing steam plasma 200 into the exhaust gas to remove carbon dioxide together.

Although the carbon dioxide reduction device using steam plasma of the present disclosure has been described with reference to an example applied to a ship engine, the present disclosure is not limited thereto, and may be used to remove carbon dioxide by being installed in exhaust systems of various facilities using fossil fuels, such as power generation engines and large boilers.

<Explanation of Symbols>

10: Plasma catalyst spray module 20: Plasma head

22: Plasma torch 23: Plasma nozzle

25: Discharge guide pipe 26, 27: Flange

29: Connecting member

30: Sub-unit 31: Controller

33: Power supplier 34: Power cable

35: Gas supplier 36: Gas supply pipe

50: Electromagnetic wave generator 52: Waveguide

54: Inclined surface 55: Connecting flange

70: Catalyst injector 72: Catalyst supply pipe

80: Steam supplier 82: Steam supply pipe

100: Scrubber 110: Seawater supply pipe

120: Inlet pipe

130: Outlet pipe

A: Inclination angle

150: Main controller

200: Plasma

CLAIMS

WHAT IS CLAIMED IS:

Claim 1: A carbon dioxide reduction device using steam plasma, wherein at least one carbon dioxide reduction device is coupled to at least any one side of an inlet pipe or an outlet pipe of a scrubber through which exhaust gas passes to remove carbon dioxide in the exhaust gas, the carbon dioxide reduction device comprising:

a plasma catalyst spray module provided with a plasma head having a front end part which penetrates and is coupled to an outer circumferential surface of the inlet pipe or the outlet pipe of the scrubber to discharge plasma from a lateral side of the exhaust gas passing through the inlet pipe or the outlet pipe,

an electromagnetic wave generator coupled to an outer circumferential surface of the plasma head to transmit electromagnetic waves to the plasma emitted within the plasma head,

a catalyst injector coupled to the outer circumferential surface of the plasma head to spray a catalyst which removes carbon dioxide contained in the exhaust gas to the plasma, and

a steam supplier coupled to the outer circumferential surface of the plasma head to spray high-temperature steam from a lateral side to the plasma to form steam plasma.

Claim 2: The carbon dioxide reduction device according to claim 1, wherein the plasma head comprises:

a plasma torch configured to generate and discharge the plasma, and

a discharge guide pipe of a hollow structure having a front end part coupled to the inlet pipe or the outlet pipe and a rear end part coupled to a front end part of the plasma torch to guide the plasma.

Claim 3: The carbon dioxide reduction device according to claim 2, wherein a plurality of plasma heads are installed radially at predetermined intervals along the outer circumferential surface of the inlet pipe or the outlet pipe, and the

plasma is discharged toward an inner center point of the inlet pipe or the outlet pipe.

Claim 4: The carbon dioxide reduction device according to claim 2, wherein a plurality of plasma heads are installed at predetermined intervals along the outer circumferential surface of the inlet pipe or the outlet pipe, and

installed to be inclined in a radial direction of the inlet pipe or the outlet pipe so that the plasma is discharged toward between an inner center point and an inner circumferential surface of the inlet pipe or the outlet pipe to be movable while rotating along the inner circumferential surface of the inlet pipe or the outlet pipe.

Claim 5: The carbon dioxide reduction device according to claim 2, wherein the plasma head is installed to be inclined in a longitudinal direction of the inlet pipe or the outlet pipe so that the plasma is discharged inclined at a predetermined angle toward a proceeding direction of the exhaust gas.

Claim 6: The carbon dioxide reduction device according to claim 2, wherein the catalyst injector is provided with a catalyst supply pipe coupled to an outer circumferential surface of the discharge guide pipe,

wherein the catalyst supply pipe is installed so as to spray the catalyst from the lateral side of the plasma by being coupled between a location where the electromagnetic wave is transmitted to the plasma and a plasma nozzle from which the plasma is emitted.

Claim 7: The carbon dioxide reduction device according to claim 6, wherein the steam supplier is provided with a steam supply pipe coupled to the outer circumferential surface of the discharge guide pipe,

wherein the steam supply pipe is installed between the catalyst supply pipe and the plasma nozzle.

Claim 8: The carbon dioxide reduction device according to any one of claims 1 to 7, wherein the catalyst injector uses sodium hydroxide (NaOH) or potassium hydroxide (KOH) as the catalyst.