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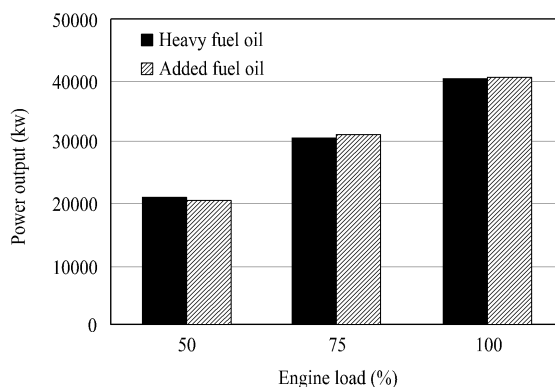
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(54) **FUEL ADDITIVE FOR REDUCING GREENHOUSE GASES, NITROGEN OXIDES AND PARTICULATE MATTER**

(57) The present disclosure provides a fuel additive for a heavy fuel oil in composition form, in which the fuel additive includes: an oil soluble metallic compound; an oxygen carrier; a dispersant; a lubricant; a non-ionic surfactant; and a detergent. If a small amount (0.025%) of the fuel additive of the present disclosure is added to a heavy fuel oil, the generation of particulate matter (PM), residual carbons, nitrogen oxides and the like upon com-

bustion can be reduced. In addition, if a small amount (0.025%) of the fuel additives of the present disclosure is added to a heavy fuel oil, the combustion efficiency can be enhanced since upon combustion, a maximum combustion pressure is increased, whereas an exhaust temperature is lowered. Thus, the fuel additive of the present disclosure is very useful for a large boiler using a heavy fuel oil as fuel, in particular, a large diesel engine.

FIG. 2



Description**[Technical Field]**

5 **[0001]** The present disclosure relates to a fuel additive capable of reducing the generation of greenhouse gases, nitrogen oxides, and particulate matter and improving combustion efficiency by being added to a heavy fuel oil during combustion in an internal combustion engine or a boiler using a heavy fuel oil as fuel.

[Background Art]

10 **[0002]** In order to slow down global warming, IMO MEPC has proposed to lower ship speed and sail as a way of reducing CO₂ which is the GHG (Green House Gas) emitted by ships. In order to reduce fuel costs, shipping companies also voluntarily lower steaming, and most of the container ships engaged in international voyages are lowering streaming. In addition, the increase in the shipping volume, which is increasing day by day, increases the burden on the fuel cost of the ship, and thus the development of fuel cost reduction technology is urgently required.

15 **[0003]** Most ships using two stroke large diesel engines operating on international voyages use a heavy fuel oil for ships. Since the heavy fuel oil has a high kinematic viscosity, there is a disadvantage in that it cannot be used unless heated to 100°C or higher. In order to lower the kinematic viscosity of heavy fuel oil with a high kinematic viscosity, which is a disadvantage, Ryu et al. made an attempt to study to lower the kinematic viscosity of heavy fuel oil by mixing it with dimethyl ether having a low kinematic viscosity. As a result, the kinematic viscosity of heavy fuel oil was lowered and applied to a diesel engine for ships without heating. In this study, it was confirmed that engine performance can also be improved by using a heavy fuel oil mixed with dimethyl ether which is attracting attention as an alternative fuel for a diesel engine. In addition, many studies and demonstrations have been made on fuel additives for diesel engines in various fields.

25 **[0004]** Fuel cost accounts for a large part of the budget expenditure of shipping companies operating and managing ships. Most domestic and overseas shipping companies are sailing ships by lowering ship speed to save fuel costs. However, when low-load operation continues for a long time in a state where a high-output engine is mounted, there arises a problem that maintenance costs are increased due to generation of carbon and increase in failure rate due to incomplete combustion. In addition, the burden on the fuel cost of ships increasing day by day urgently requires the development of technology to save fuel cost to shipowners.

30 **[0005]** In order to solve these problems, researches on fuel additives that can minimize the generation of residual carbon powder, dust, or sulfur dust, etc. in the combustion of heavy fuel oil or improve the combustion efficiency have been made intermittently. For example, Korean Patent Registration Publication No. 10-0743826 discloses a fuel additive for a bituminous heavy fuel oil/water emulsion including 30 to 60% by weight of magnesium hydroxide having a particle size of 0.1 to 10 μm; 0.1 to 1% by weight of polycarboxylic acid and/or its salt; and the water of the remaining % by weight.

35 **[0006]** In addition, Korean Patent Registration Publication No. 10-1071204 discloses a fuel additive for a heavy fuel oil consisting of a composition including 25 to 55% by weight of an oil soluble metallic compound including any one of calcium, barium, manganese or iron, 15 to 25% by weight of alcohol, 10 to 20% by weight of hydrotreated light distillate, 5 to 15% by weight of kerosene, 5 to 15% by weight of mineral oil, and 2 to 8% by weight of non-ionic surfactant, in which the mineral oil is composed of one or more kinds selected from the group consisting of a hydrotreated heavy paraffinic distillate or a hydrotreated light paraffinic distillate, solvent-dewaxed heavy paraffinic distillate, solvent-dewaxed light paraffinic distillate, hydrotreated and dewaxed heavy paraffinic distillate, and hydrotreated and dewaxed light paraffinic distillate.

[Disclosure]**[Technical Problem]**

50 **[0007]** The present disclosure has been made under the background of the prior art, and an object of the present disclosure is to provide a method for reducing the generation of greenhouse gases, nitrogen oxides and particulate matter added to a heavy fuel oil during combustion in an internal combustion engine or a boiler using a heavy fuel oil as fuel, and to provide a fuel additive capable of improving combustion efficiency.

[Technical Solution]

55 **[0008]** In order to achieve the above object, one aspect of the present disclosure provides a fuel additive for a heavy fuel oil in the form of a composition including an oil soluble metallic compound, an oxygen supplier, a dispersant, a lubricant, a non-ionic surfactant, and a detergent. Hereinafter, the fuel additive for a heavy fuel oil according to the

present disclosure will be described separately for each constituent component.

Oil soluble metallic compound

[0009] The oil soluble metallic compound, which is one of the components of the fuel additive for a heavy fuel oil according to the present disclosure, increases the reactivity with oxygen during the combustion of heavy fuel oil, which is fuel oil, accelerates the oxidation and promotes the combustion reaction of low combustibility components such as asphaltenes, and acts as a combustion promoter for suppressing generation of exhaust gas and dust. In the present disclosure, the oil soluble metallic compound preferably includes a metal having a high combustion promoting reactivity, and at the same time has a property of being oil soluble in fuel-derived heavy oil. Examples of the metal having a high combustion promoting reactivity include calcium, barium, manganese or iron, etc. In the present disclosure, it is preferable that the oil soluble metallic compound is composed of an active metal portion and an organic ligand in order to be well dissolved in fuel-derived heavy oil. Examples of the oil soluble metallic compound include calcium acetylacetonate, calcium naphthenate, calcium oxalate, barium acetylacetonate, barium naphthenate, barium oxalate, manganese acetylacetonate, manganese naphthenate, manganese oxalate, iron acetylacetonate, iron naphthenate, iron oxalate, etc. In addition, in the present disclosure, the oil soluble metallic compound may be a metal salt of a carboxylic acid or a metal salt of a sulfonic acid from a different viewpoint.

[0010] In consideration of the relative size of the combustion promoting reactivity, the oil soluble metallic compound in the present disclosure is most preferably an oil soluble metallic compound including calcium. For example, it may be composed of at least one selected from the group consisting of calcium salt of sulfonic acid, calcium acetylacetonate, calcium naphthenate or calcium oxalate. The calcium salt of the sulfonic acid includes an organic functional group such as an alkyl group, an aryl group, or an alkylaryl group, and is preferably a calcium alkylbenzenesulfonate including a double alkylaryl group. The alkyl group of the calcium alkylbenzenesulfonate is characterized by having 8 to 50 carbon atoms. A specific example of the calcium alkylbenzenesulfonate is calcium dodecylbenzenesulfonate, which is a typical anionic surfactant.

[0011] In the fuel additive for a heavy fuel oil according to the present disclosure, the content of the oil soluble metallic compound is 20 to 25 wt% based on the total weight of the composition, considering the effect of minimizing dust generation and compatibility with other constituents.

Oxygen carrier

[0012] Even if excessive combustion air is supplied during heavy fuel oil combustion, the rate of exhaustion by the combustion reaction such as heterogeneous surface reaction is higher than the diffusion rate of oxygen, so that the oxygen concentration becomes thin at the interface where the combustion reaction occurs, thereby causing an oxygen deficiency phenomenon. The oxygen carrier which is one component of the fuel additive for a heavy fuel oil according to the present disclosure is preferably a compound having a low boiling point. The low boiling point compound can contribute to complete combustion by increasing the combustion reaction surface area by the vaporization phenomenon inside a burner spray droplet.

[0013] The low boiling point compound used as an oxygen carrier in the present disclosure may preferably be composed of at least one selected from the group consisting of dialkyl ether compounds, dialkyl ether compounds of ethylene glycol, dialkyl ether compounds of propylene glycol, butylene glycol dialkyl ether compounds, dialkyl ketone compounds, dialkoxy alkane compounds or dialkyl carbonate compounds, in which the alkyl group, alkoxy group or alkane preferably has 1 to 5 carbon atoms.

[0014] Specific examples of the oxygen carrier may preferably be composed of at least one selected from the group consisting of methyl propyl ether, diisopropyl ether, ethyl methyl ether, ethylene glycol dimethyl ether, ethylene glycol diethyl ether, propylene glycol dimethyl ether, dimethyl ketone, acetyl acetone, methylpropyl ketone, ethylmethyl ketone, isobutylmethyl ketone, dimethoxy methane, dimethyl carbonate, diethyl carbonate, dipropyl carbonate, diisopropyl carbonate, dibutyl carbonate, dipentyl carbonate, methylethyl carbonate, methyl propyl carbonate or ethyl propyl carbonate, etc. Among these, it is preferably composed of at least one selected from the group consisting of dimethyl carbonate, diethyl carbonate, diisopropyl carbonate, diisopropyl carbonate, dibutyl carbonate, dipentyl carbonate, methylethyl carbonate, methylpropyl carbonate, or ethylpropyl carbonate.

[0015] In the fuel additive for a heavy fuel oil according to the present disclosure, the content of the oxygen carrier is preferably 30 to 35% by weight based on the total weight of the composition, considering the effect of minimizing dust generation and compatibility with other components.

Dispersant

[0016] The dispersant, which is one component of the fuel additive for a heavy fuel oil according to the present

disclosure, plays a role in preventing the formation of sludge, lowering the flash point of the heavy fuel oil, and reducing the kinematic viscosity and surface tension. When the viscosity and the surface tension of the heavy fuel oil are reduced, the particle diameter of the fuel becomes atomized and homogenized at the time of injection from the nozzle, and it is possible to lower the temperature of the exhaust gas of the internal combustion engine by the rapid combustion and the low temperature explosion at the time of combustion. In the present disclosure, the dispersant is a hydrotreated light distillate.

[0017] Hydrotreated is a treatment method of adding hydrogen to oil, etc. In addition, the light distillate refers to a light hydrocarbon which is distilled first when the crude oil is distilled. The hydrotreated light distillate has a boiling point of usually 150 to 300°C, but is not limited thereto. The hydrotreated light distillate which can be used in the present disclosure includes products such as CAS Registration Nos. 64742-47-8 and 68921-07-3, but is not limited thereto.

[0018] In the fuel additive for a heavy fuel oil according to the present disclosure, the content of the hydrotreated light distillate is preferably 15 to 20% by weight based on the total weight of the composition, considering the effect of reducing the flash point and the kinematic viscosity, minimizing the generation of dust and residual carbon powder and the compatibility with other components.

Lubricant

[0019] The lubricant, which is one component of the fuel additive for a heavy fuel oil according to the present disclosure, plays a role in maintaining the shape of sludge redispersed in the form of microparticles and suppressing the occurrence of friction in an internal combustion engine. In the present disclosure, the lubricant is preferably a paraffinic oil, more preferably modified by hydrotreating or dewaxing treatment. The paraffinic oil modified by the hydrotreating or dewaxing treatment may be composed of at least one selected from the group consisting of a hydrotreated heavy paraffinic distillate (CAS Registration No. 64742-54-7), a hydrotreated light paraffinic distillate (CAS Registration No. 64742-55-8), a solvent-dewaxed heavy paraffinic distillate (CAS Registration No. 64742-65-0), a solvent-dewaxed light paraffinic distillate (CAS Registration No. 64742-56-9), a hydrotreated and dewaxed heavy paraffinic distillate (CAS Registration No. 91995-39-0) or a hydrotreated and dewaxed light paraffinic distillate (CAS Registration No. 91995-40-3), but is not limited thereto.

[0020] In the fuel additive for a heavy fuel oil according to the present disclosure, the content of the lubricant is preferably 3 to 7% by weight based on the total weight of the composition, considering the effect of reducing the flash point and the kinematic viscosity, minimizing the generation of dust and residual carbon powder and the compatibility with other components.

Non-ionic surfactant

[0021] The non-ionic surfactant, which is one component of the fuel additive for a heavy fuel oil according to the present disclosure, plays a role in preventing the formation of sludge and redispersing the generated sludge into a microparticle. In particular, the non-ionic surfactant exhibits a repulsion due to steric hindrance to form a stable dispersion system. When used in combination with an ionic material such as an oil soluble metallic compound, dispersion performance is greatly improved.

[0022] The non-ionic surfactant used in the present disclosure is not greatly limited in its kinds such as ester base, ether base, fatty acid amide base, aliphatic amine derivative, and the like. Examples of the ester-based non-ionic surfactant include sorbitan esters of fatty acids, pentaerythritol esters of fatty acids, propyleneglycol monoesters of fatty acids, glycerin monoesters of fatty acids, polyethyleneglycol sorbitan esters of fatty acids, polyethyleneglycol sorbitol esters of fatty acids, and polyethyleneglycol esters of fatty acids, and the like. Examples of the ether-based non-ionic surfactant include polyoxyethylene alkyl ethers, polyoxyethylene alkyl phenyl ethers, alkylpolyglycosides, and the like. Examples of the fatty acid amide-based non-ionic surfactant include fatty acid dialkanolamides, fatty acid monoalkanolamides, polyoxyethylene fatty acid amides, and the like. Examples of the aliphatic amine derivative non-ionic surfactant include polyoxyethylene alkylamine, and the like. Considering the effect of reducing the flash point and the kinematic viscosity, minimizing the generation of dust and residual carbon powder and the compatibility with other components, the non-ionic surfactant used in the present disclosure may be preferably composed of at least one selected from the group consisting of sorbitan esters of fatty acids, polyethyleneglycol esters of fatty acids, or polyethylene glycol sorbitan esters of fatty acids.

[0023] Examples of sorbitan esters of fatty acids include sorbitan monooleate, sorbitan monolaurate, and the like. Examples of the polyethyleneglycol sorbitan esters of fatty acids include polyethylene glycol sorbitan monooleate, and the like. Examples of the polyethyleneglycol esters of fatty acids include polyethylene glycol dilaurate, polyethylene glycol monooleate, polyethylene glycol dioleate, polyethylene glycol monoricinoleate, polyethylene glycol monostearate, and the like.

[0024] In the fuel additive for a heavy fuel oil according to the present disclosure, the content of the non-ionic surfactant is preferably 8 to 15% by weight based on the total weight of the composition, considering the effect of reducing the

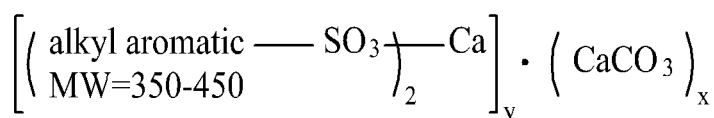
flash point and the kinematic viscosity, minimizing the generation of dust and residual carbon powder and the compatibility with other components.

Detergent

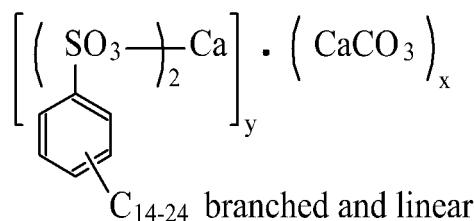
[0025] The detergent, which is one component of the fuel additive for a heavy fuel oil according to the present disclosure, plays a role in decomposing the secondary oxide and the combustion products to reduce the formation of precipitates on the surface of the metal parts surface. The detergent used in the present disclosure may be composed of at least one selected from the group consisting of alkaline metal salts of a known sulfonate, alkaline earth metal salts of sulfonates, alkaline metal salts of phenates, alkaline earth metal salts of phenates, alkaline metal salts of salicylates, alkaline earth metal salts of salicylates, alkaline metal salts of naphthenate, or alkaline earth metal salts of naphthenate. The alkaline metal or alkaline earth metal is preferably selected from calcium, magnesium, sodium, or barium.

[0026] The metal salt-type detergent may include a metal in a stoichiometric amount or in excess thereof. In the latter case, it is treated as an overbased detergent. The overbased detergent is a metal salt that dissolves in oil and appears as a micelle consisting of an insoluble metal salt trapped in a suspension in a fuel oil composition described later. The overbased characteristic of the detergent is characterized by total base number (TBN), measured in accordance with ASTM D2896 standard, and is expressed in mg of KOH per gram. The overbased detergent itself typically has a TBN value of about 150 or more, or 250 or 450 or more. In the present disclosure, it is preferable that the detergent is an overbased detergent in consideration of the synergistic effect with other components. In addition, in the present disclosure, the TBN of the overbased detergent is preferably 200 or more, more preferably 300 or more. The overbasing process is well known in the pertinent art and typically involves reacting an acidic material with a reaction mixture including an organic acid or metal salt thereof, or a metal compound. The acidic material may be a gas such as carbon dioxide or sulfur dioxide, or it may be boric acid. A method for preparing an overbased alkaline metal sulfonate and phenate is described in U.S. Patent No. 4,839,094. A suitable method for an overbased sodium sulfonate is described in EP-A-235929. A method for preparing an overbased salicylate is described in U.S. Patent No. 5,451,331. In addition, commercially available overbased detergents include T106 (Overbased Heavy alkyl benzene synthetic calcium sulfonate of Anneng Chemical Co., Ltd. (CAS registration no. 61789-86-4)), CALCINATE™ C-300CS of Chemtura Corporation, OLOA 246S (Sulfonic acids, petroleum, calcium salts, overbased (CAS Registration No. 68783-96-0)) of Chevron Chemical Company, and the like. In addition, the overbased sulfonate-based detergent of CAS Registration No. 68783-96-0 has the structure of the following Formula 1, and the overbased sulfonate-based detergent of CAS Registration No. 115733-10-3 has the structure of the following Formula 2.

[Formula 1]



[Formula 2]



[0027] In the fuel additive for a heavy fuel oil according to the present disclosure, the content thereof is preferably 7 to 15% by weight based on the total weight of the composition, considering the effect of improving combustion of the detergent, reducing NOx, minimizing the generation of dust and residual carbon powder and the compatibility with other components.

[0028] In addition, another aspect of the present disclosure relates to a fuel oil based on a heavy fuel oil, in which the fuel oil based on a heavy fuel oil according to the present disclosure includes a heavy fuel oil and the above-described fuel additives for a heavy fuel oil. At this time, the heavy fuel oil is not limited in its kind, and may be a heavy oil A, a

heavy oil B, a heavy oil C (or bunker C oil), or a mixed heavy oil thereof. In addition, the content of the fuel additive for a heavy fuel oil in the fuel oil is not limited to a great extent. However, considering the effect of reducing the flash point and the kinematic viscosity of fuel additives, minimizing the generation of dust and residual carbon powder, reducing NOx and improving combustion efficiency, and the economic feasibility of a fuel oil, it is preferably 0.001 to 0.5 parts by weight, more preferably 0.005 to 0.1 parts by weight, per 100 parts by weight of the heavy fuel oil.

[Advantageous Effects]

[0029] If a small amount (0.025%) of the fuel additive of the present disclosure is added to a heavy fuel oil, the generation of particulate matter (PM), residual carbons, nitrogen oxides and the like upon combustion can be reduced. In addition, if a small amount (0.025%) of the fuel additives of the present disclosure is added to a heavy fuel oil, the combustion efficiency can be enhanced since upon combustion, a maximum combustion pressure is increased, whereas an exhaust temperature is lowered. Thus, the fuel additive of the present disclosure is very useful for a large boiler using a heavy fuel oil as fuel, in particular, a large diesel engine.

[Description of Drawings]

[0030]

FIG. 1 is a schematic diagram of an experimental apparatus for an engine used in this study.

FIG. 2 is a graph illustrating the increase and decrease ratio of the output at each load depending on whether the fuel additive is added in the present study.

FIG. 3 is a graph illustrating the results of the fuel consumption rate depending on whether the fuel additive is added in the present study.

FIG. 4 is a graph illustrating the results of the maximum combustion pressure of the engine depending on whether the fuel additive is added in the present study.

FIG. 5 is a graph illustrating the exhaust temperatures after combustion of the engine at various loads depending on whether the fuel additive is added in the present study.

[Detailed Description of Embodiment]

[0031] Hereinafter, the present disclosure will be described in more detail with reference to examples. However, the following examples are intended to clearly illustrate the technical features of the present disclosure and do not limit the scope of protection of the present disclosure.

[0032] The applicant of the present disclosure attempted to reduce the fuel cost by injecting a predetermined fuel additive (including an oil-soluble calcium-based organometallic compound as one component) into a heavy fuel oil for ships. Specifically, a method of reducing a fuel cost by injecting a predetermined amount of a fuel additive (including an oil-soluble calcium-based organometallic compound as one component) (0.025% of a fuel amount used) was tried. For the accuracy of the experiment, a two-stroke large diesel engine installed in the land-based power plant was an experiment object. The experimental engine load was divided into low, medium and high load (50, 75, 100%). The engine performance (output, fuel consumption rate, maximum combustion pressure (P-max), exhaust temperature) before and after the injection of fuel additives was compared and analyzed. Through this experiment, it was confirmed that the addition of the fuel additive reduced the fuel cost by 2% or more at the low load (50%), and that the maximum combustion pressure was increased while the exhaust temperature was lowered. Hereinafter, the research conducted by the applicant of the present disclosure will be described in detail.

1. Preparation of fuel additives used in experiments

[0033] 23 parts by weight of calcium alkylbenzenesulfonate (Benzenesulfonic acid, mono-C15-30-branched alkyl and di-C11-13-branched and linear alkyl derivs., calcium salts; CAS Registration No. 71486-79-8), 32 parts by weight of dimethyl carbonate, 18 parts by weight of a hydrotreated light distillate (CAS Registration No. 64742-47-8), 5 parts by weight of a hydrotreated heavy paraffinic distillate (CAS Registration No. 64742-54-7), 12 parts by weight of sorbitan monooleate (CAS Registration No. 1338-43-8) and 10 parts by weight of an overbased calcium sulfonate detergent (Benzenesulfonic acid, C14-24-branched and linear alkyl derivatives, calcium salts, overbased; CAS Registration No. 115733-10-3) were mixed and stirred to prepare a fuel additive including an oil-soluble calcium-based organometallic compound.

2. Experimental apparatus and method

[0034] In this study, for the accuracy of the experiment, a two-stroke large diesel engine installed in the land-based power plant was an experiment object. The fuel additives were injected at a rate of 0.025% of the fuel used to perform an experiment. The experiments were carried out after the load of the experimental engine had a stable thermal equilibrium at the exhaust temperature, and was divided into three stages: low, medium and high load (50, 75, 100%) for the experiments. It was maintained constant within the range of $\pm 3\%$ of Load Limiter, and the generator output voltage was maintained and driven at the rated voltage. And the engine performance (output, fuel consumption rate, maximum combustion pressure (P-max), exhaust temperature) before and after the injection of fuel additives was compared and analyzed. Table 1 exhibits the specifications of the experimental engine used in this study. The equipment to be applied for the performance experiment is Diesel Engine Generator equipment manufactured and installed by Doosan Engine Co., Ltd, and is a 40MW generator. And Table 2 exhibits the properties of the fuels used in this study and exhibits the fuel properties of heavy fuel oil after injecting fuel additives at 0.025% ratio of heavy fuel oil and the fuel properties of heavy fuel oil before injecting them into a heavy fuel oil for ships. As the fuel additive, an additive including an oil-soluble calcium-based organometallic compound was used. To analyze the fuel composition of each fuel, three samples were collected during the experiment to analyze the exact composition of the fuel. The analysis was commissioned by a domestic fuel analysis agency

[Table 1]

Item	Description
Engine type	Low speed two stroke cycle, 12K80MC-S
Bore $\times$ Stroke	800mm $\times$ 2300mm
Combustion type	Direct injection type
No. of cylinders	12
MCR output	41,320 kW
MCR rpm	109.1 rpm
Mean effective pressure	16.4 kg _f /cm ²
Mean piston speed	8.36 m/s
Weight	1,413 ton
Turbo charger rpm	11,000 rpm
Firing order	1-5-12-7-2-6-10-3-8-4-11-9

[Table 2]

Item	Heavy fuel oil	Added fuel oil
Density at 15°C, g/ml	0.9384	0.9378
Ash, mass%	0.042	0.030
Sulfur, mass%	0.254	0.273
Viscosity at 100°C, mm ² /s	24.27	23.39
Water by distillation, volume%	0.10	0.20
Nitrogen, mass%	0.33	0.32
Gross calorific value, kcal/kg	10,550	10,546
Net calorific value, kcal/kg	9,940	9,934
Carbon, mass%	86.68	86.56
Hydrogen, mass%	12.04	12.07

(continued)

Item	Heavy fuel oil	Added fuel oil
Oxygen, mass%	0.65	0.75
* Heavy fuel oil: Heavy fuel oil before injecting fuel additives * Added fuel oil: Heavy fuel oil into which fuel additives are injected at a ratio of 0.025%		

[0035] The fuel additive injection system installed a dosing pump that can automatically supply a certain amount around the control tank, and the supply position is connected to a supply piping so that it can be supplied to the top of the fuel control tank. In addition, the engine output was measured in a local integrated watt-hour meter and a control room meter, and the fuel consumption amount was referred to an on-site mass flowmeter reading installed on the fuel oil supply line side. Table 3 exhibits the dosing pump and mass flowmeter specifications. In calculating the engine output and fuel consumption rate, each item on the performance was calculated by applying the calibration curve and formula given by the manufacturer. FIG. 1 is a schematic diagram of an experimental apparatus for an engine used in this study.

[Table 3]

Item	Description
Dosing pump	CMG Techwin, AX1-12 model, 110 mL/min
Mass flowmeter	Endress Hauser, IP67/NEMA/TYPE4X model

3. Experimental results and consideration

3.1 Engine power output

[0036] The engine output was measured by dividing them into three stages of low, medium and high load (50, 75, 100%). At the low load of 50% of the engine load, the average value measured 4 times is exhibited. At the medium load of 75% and the high load of 100% of the engine load, the average value measured 7 times is exhibited. Table 4 exhibits the rate of increase and decrease of the output at each load, and FIG. 2 illustrates the results thereof in the form of a graph. At a low load of 50%, the output decreased by about 2.1%, but increased by about 1.6% and 0.4% at 75% of medium load and 100% of high load, respectively. These results indicate that the output is improved by completely combusting the unburned matter with the fuel additive effect at a load of 75% or more. This engine output value is a value obtained by calibrating the measured output value with the design Gen power factor value. These results exhibit that the engine power is improved in medium and heavy load regions rather than in a low load when the fuel additive is injected into a heavy fuel oil.

[Table 4]

Load(%)	HFO(kW)	Added fuel(kW)	Difference	Ratio(%)
50	21,186	20,748	-438	-2.11
75	30,521	31,016	495	1.60
100	40,460	40,605	145	0.36
* HFO: Heavy fuel oil before injecting fuel additives * Added fuel: Heavy fuel oil into which fuel additives are injected at a ratio of 0.025%				

3.2 Fuel consumption rate

[0037] Table 5 and FIG. 3 exhibit the results of the fuel consumption rate. At the low load of 50% of the engine load, the average value measured 4 times is exhibited. At the medium load of 75% and the high load of 100% of the engine load, the average value measured 7 times is exhibited. At a low load, the fuel consumption rate decreased by about 2.2%, and decreased by about 0.7% and 0.8% of medium and high loads. It is determined that these results are produced by combustion promotion. That is, it was confirmed that the fuel efficiency was improved at full load by injecting the fuel additive into the heavy fuel oil. In particular, the fuel consumption reduction rate was higher at low load than at medium and high load regions.

[Table 5]

Load(%)	HFO(g/kWh)	Added fuel(g/kWh)	Difference	Ratio(%)
50	207.430	202.833	-4.597	-2.27
75	186.395	185.103	-1.292	-0.70
100	188.422	186.913	-1.509	-0.81
* HFO: Heavy fuel oil before injecting fuel additives * Added fuel: Heavy fuel oil into which fuel additives are injected at a ratio of 0.025%				

3.3 Maximum combustion pressure (P-max)

[0038] Table 6 and FIG. 4 exhibit the results of the maximum combustion pressure of the engine. Each value was measured after all cylinders 12 cylinders were measured, and the average value was exhibited. The maximum combustion pressure increased about 3.0% at low load and increased about 6.6% and 0.9% at medium and high load, respectively. That is, it was confirmed that the maximum combustion pressure was increased at full load by injecting the fuel additive into the heavy fuel oil for ships. In particular, it exhibits a large increase rate in medium load of 75%, which is the commercial load of the engine. As exhibited in Table 2, it is analyzed that engine combustion is promoted actively by the action of oxygen included in the fuel additive, thereby improving combustion.

[Table 6]

Load(%)	HFO(Bar)	Added fuel(Bar)	Difference	Ratio(%)
50	86.25	88.83	2.58	2.90
75	114.83	122.91	8.08	6.57
100	139.83	141.08	1.25	0.89
* HFO: Heavy fuel oil before injecting fuel additives * Added fuel: Heavy fuel oil into which fuel additives are injected at a ratio of 0.025%				

3.4. Exhaust temperature

[0039] Table 7 and FIG. 5 exhibit the post-combustion temperature of the engine at each load. Each value was measured after all cylinders 12 cylinders were measured, and the average value was exhibited. At the low load, the exhaust temperature decreased by about 2.7%, and at medium and high loads, it decreased by about 2.4% and 0.6%. That is, it was confirmed that the exhaust temperature decreases at full load by injecting the fuel additive into the heavy fuel oil. It is determined that the asphalt and sludge included in the heavy fuel oil are well dispersed by the dispersant included in the fuel additive, thereby producing the fuel atomization and homogenization effect of fuel during the fuel injection so as to be stable combustion.

[Table 7]

Load(%)	HFO(°C)	Added fuel(°C)	Difference	Ratio(%)
50	337.08	328.08	-9.00	-2.74
75	326.42	318.83	-7.59	-2.38
100	343.08	341.17	-1.91	-0.56
* HFO: Heavy fuel oil before injecting fuel additives * Added fuel: Heavy fuel oil into which fuel additives are injected at a ratio of 0.025%				

4. Conclusion

[0040] In this study, a two-stroke high-power large diesel engine was tested using a standardized measurement equipment on the land that is not affected by the ocean and weather conditions. In order to compare and analyze the engine performance (engine output, fuel consumption rate, maximum combustion pressure, exhaust temperature) before

and after injection into the fuel additive of heavy fuel oil for ships, experiments were carried out at low, medium and high loads (50, 75, 100%) of the engine, and the following research results were obtained.

(1) At low loads with 50% engine load, the output decreased by about 2.1%, but increased by about 1.6% and 0.4% at 75% medium load and 100% high load of an engine load, respectively. These results exhibit that the engine output is improved in medium and heavy load regions rather than in low load when the fuel additive is injected into a heavy fuel oil.

(2) Fuel consumption rate decreased by about 2.2% at low load and about 0.7% and 0.8% at medium and high load, respectively. That is, it was confirmed that the fuel efficiency was improved at full load by injecting the fuel additive into the heavy fuel oil. In particular, the fuel consumption reduction rate was higher at low load than at medium and high load regions.

(3) The maximum combustion pressure increased by about 3.0% at low load, and about 6.6% and 0.9% at medium and high loads, respectively. That is, it was confirmed that the maximum combustion pressure was increased at full load by injecting the fuel additive into the heavy fuel oil for ships.

(4) As a result of measurement of exhaust temperature, it decreased by about 2.7% at low load, about 2.4% at medium load, and about 0.6% at high load. That is, it was confirmed that the exhaust temperature decreases at full load by injecting the fuel additive into the heavy fuel oil. It is determined that the fuel additive influences the engine combustion, so that it becomes stable combustion.

[0041] Through this study, it was confirmed that the fuel cost can be reduced by 2% or more at the low load (50%) by injecting the predetermined fuel additive including the oil soluble calcium-based organometallic compound into a heavy fuel oil for ships which is currently used in the two-stroke high-power large diesel engine. It can be understood that the maximum combustion pressure increases, whereas the exhaust temperature is lowered. Through these results, it is thought that the engine performance is improved. Accordingly, it is possible to reduce fuel costs by injecting a fuel additive into a two-stroke large diesel engine which uses a heavy fuel oil for ships.

5. Additional experiments

[0042] In addition to the above studies, the changes in exhaust emissions due to the addition of fuel additives were observed, and the results are exhibited in Tables 8 and 9 below. Table 8 exhibits the emission changes of nitrogen oxide (NOx) according to the addition of the fuel additive and Table 9 exhibits the emission change of particulate matter (PM) according to the addition of the fuel additive. As exhibited in Tables 8 and 9, when the fuel additive of the present disclosure is added to a heavy fuel oil and burned, the generation of nitrogen oxides and particulate matter is greatly reduced.

[Table 8]

load	NOx emission amount before injecting a fuel additive (g/kWh)	NOx emission amount after injecting a fuel additive (g/kwh)	Reduction rate of NOx emission amount according to the injection of a fuel additive (%)
50%	16.6	12.6	-24
75 %	21.5	11.7	-46
100%	22.4	14.3	-36
Average reduction rate of NOx emission amount according to the injection of a fuel additive (%)			-35

[Table 9]

load	PM emission amount before injecting a fuel additive(mg/m ³)	PM emission amount after injecting a fuel additive (mg/m ³)	Reduction rate of PM emission amount according to the injection of a fuel additive (%)
50%	64.1	27.3	-57.4
75%	100.8	40.9	-59.4
100%	108.6	43.8	-59.7

(continued)

load	PM emission amount before injecting a fuel additive(mg/m ³)	PM emission amount after injecting a fuel additive (mg/m ³)	Reduction rate of PM emission amount according to the injection of a fuel additive (%)
Average reduction rate of PM emission amount according to the injection of a fuel additive (%)			-58,8

[0043] From the foregoing, the present disclosure has been described by way of the above examples, but is not limited thereto. It is apparent that various modifications may be made without departing from the scope and spirit of the present disclosure. Therefore, the protection scope of the present disclosure should be construed as including all embodiments falling within the scope of the appended claims.

Claims

1. A fuel additive for a heavy fuel oil in composition form, the fuel additive comprising: an oil soluble metallic compound; an oxygen carrier; a dispersant; a lubricant; a non-ionic surfactant; and a detergent, wherein the oil soluble metallic compound includes any one of calcium, barium, manganese, or iron, wherein the oxygen carrier is composed of at least one selected from the group consisting of dialkyl ether compounds, dialkyl ether compounds of ethylene glycol, dialkyl ether compounds of propylene glycol, butylene glycol dialkyl ether compounds, dialkyl ketone compounds, dialkoxy alkane compounds or dialkyl carbonate compounds, wherein the dispersant is a hydrotreated light distillate, wherein the lubricant is composed of at least one selected from the group consisting of a hydrotreated heavy paraffinic distillate, a hydrotreated light paraffinic distillate, a solvent-dewaxed heavy paraffinic distillate, a solvent-dewaxed light paraffin distillate, a hydrotreated and dewaxed heavy paraffinic distillate or a hydrotreated and dewaxed light paraffinic distillate, wherein the detergent is composed of at least one selected from the group consisting of alkaline metal salts of a sulfonate, alkaline earth metal salts of sulfonates, alkaline metal salts of phenates, alkaline earth metal salts of phenates, alkaline metal salts of salicylates, alkaline earth metal salts of salicylates, alkaline metal salts of naphthenate, or alkaline earth metal salts of naphthenate, and wherein an alkyl group, alkoxy group or alkane of the compound forming the oxygen carrier have 1 to 5 carbon atoms.
2. The fuel additive for a heavy fuel oil according to claim 1, wherein the oil soluble metallic compound is composed of at least one selected from the group consisting of calcium salt of sulfonic acid, calcium acetylacetonate, calcium naphthenate, or calcium oxalate.
3. The fuel additive for a heavy fuel oil according to claim 1, wherein the oil soluble metallic compound is a calcium alkylbenzenesulfonate and the alkyl group has 8 to 50 carbon atoms.
4. The fuel additive for a heavy fuel oil according to claim 1, wherein the oxygen carrier is composed of at least one selected from the group consisting of dimethyl carbonate, diethyl carbonate, dipropyl carbonate, diisopropyl carbonate, dibutyl carbonate, dipentyl carbonate, methylethyl carbonate, methylpropyl carbonate, or ethylpropyl carbonate.
5. The fuel additive for a heavy fuel oil according to claim 1, wherein the non-ionic surfactant is composed of at least one selected from the group consisting of sorbitan esters of fatty acids, polyethyleneglycol esters of fatty acids, or polyethylene glycol sorbitan esters of fatty acids.
6. The fuel additive for a heavy fuel oil according to claim 5, wherein the non-ionic surfactant is composed of at least one selected from the group consisting of sorbitan monooleate, sorbitan monolaurate, or polyethyleneglycol sorbitan monooleate.
7. The fuel additive for a heavy fuel oil according to claim 1, wherein the detergent is an overbased detergent.
8. The fuel additive for a heavy fuel oil according to claim 1, the fuel additive comprising 20 to 25% by weight of an oil soluble metallic compound, 30 to 35% by weight of an oxygen carrier, 15 to 20% by weight of a dispersant, 3 to 7%

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by weight of a lubricant, 8 to 15% by weight of a nonionic surfactant, and 7 to 15% by weight of a detergent, based on a total weight of the composition.

9. A fuel oil comprising a heavy fuel oil and the fuel additive for a heavy fuel oil according to any one of claims 1 to 8.

10. The fuel oil according to claim 9, wherein the content of the fuel additive for a heavy fuel oil in the fuel oil is 0.001 to 0.5 parts by weight per 100 parts by weight of the heavy fuel oil.

FIG. 1

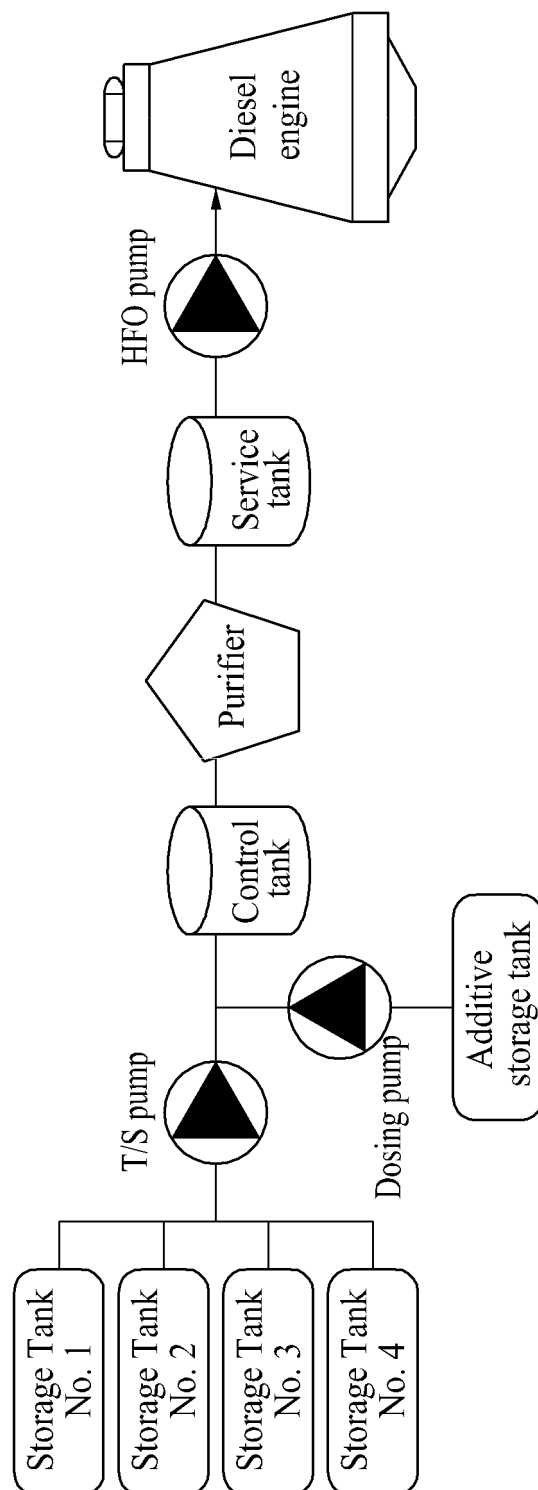


FIG. 2

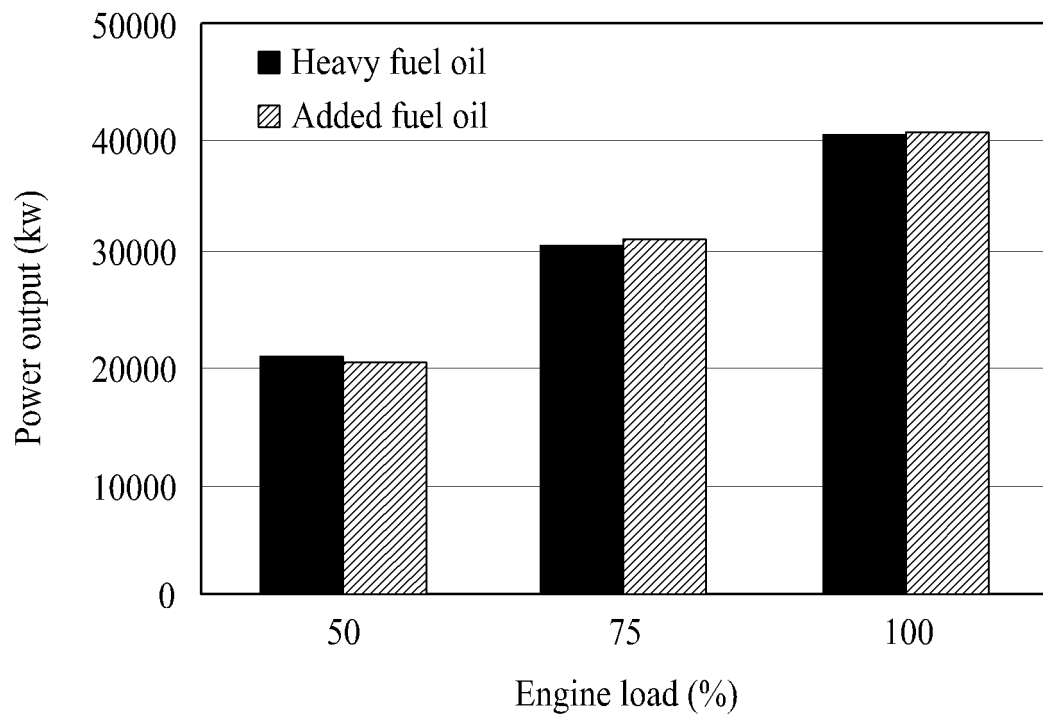


FIG. 3

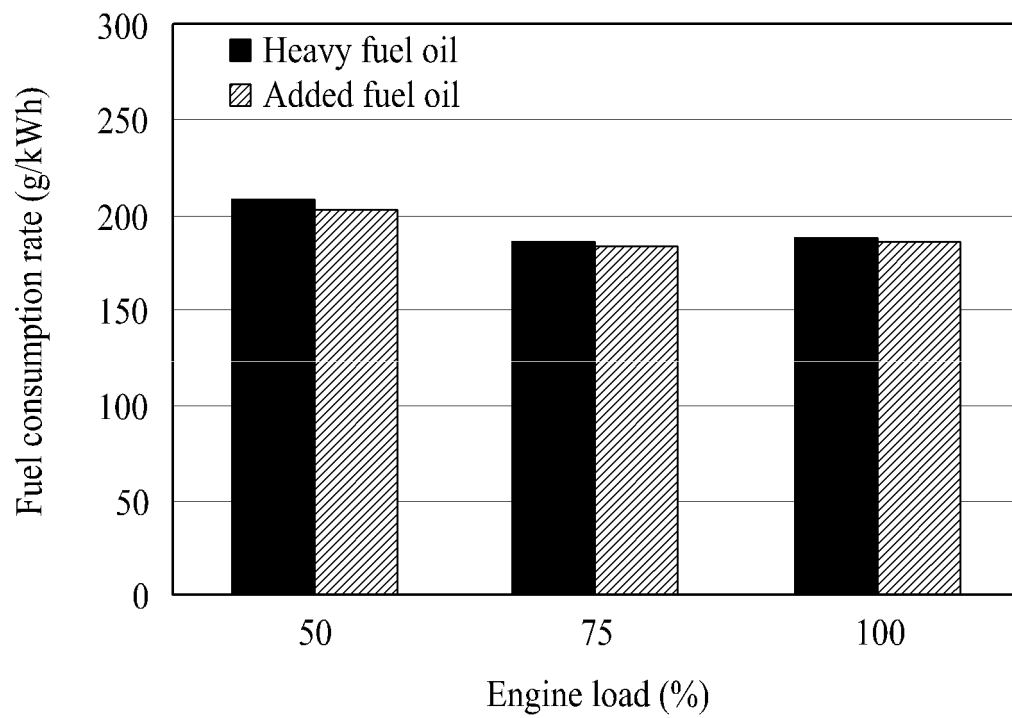


FIG. 4

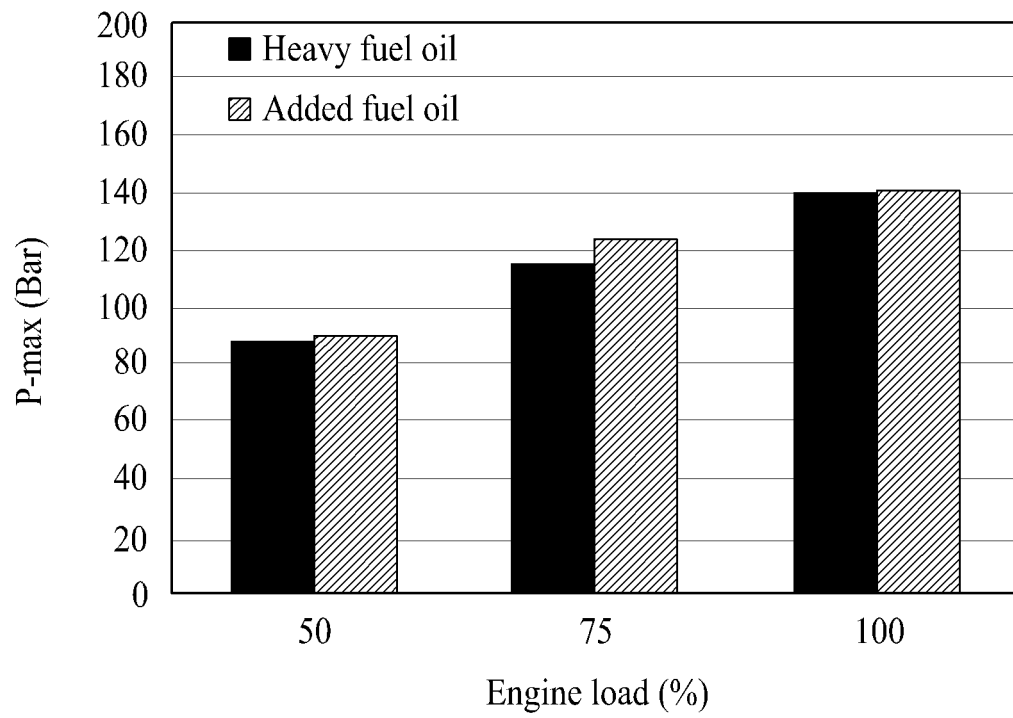
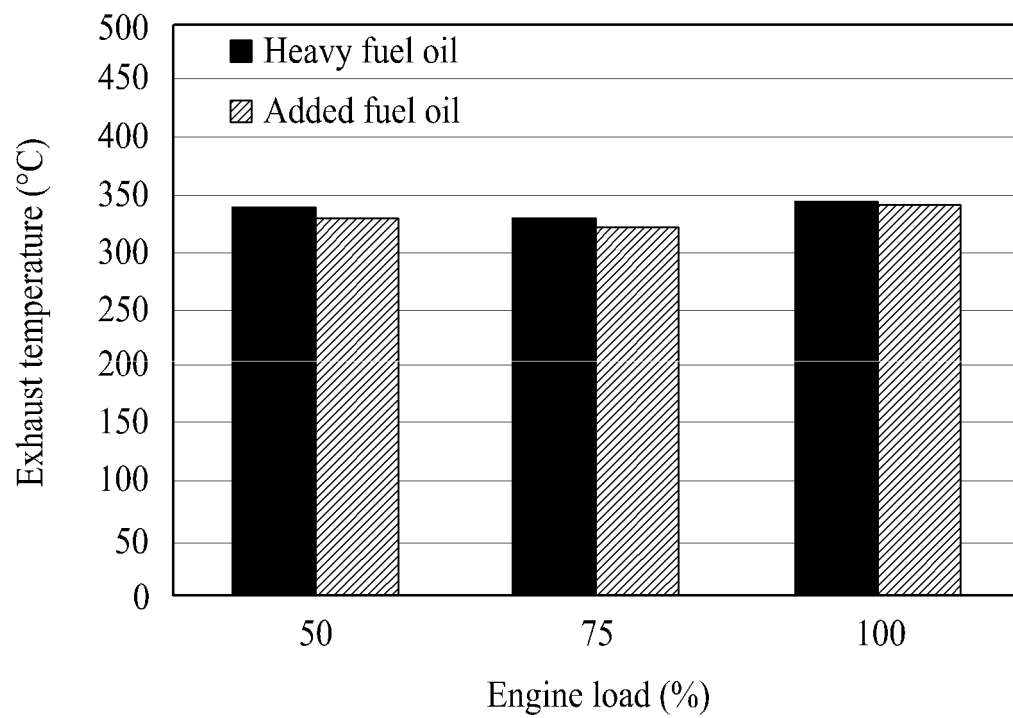


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2016/008816

A. CLASSIFICATION OF SUBJECT MATTER

C10L 1/10(2006.01)i, C10L 1/08(2006.01)i, C10L 10/02(2006.01)i, C10L 1/12(2006.01)i, C10L 1/14(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10L 1/10; F02M 25/00; C10L 1/14; C10L 1/22; C10L 1/30; C10M 135/30; C10L 1/88; C10L 1/12; C10M 141/12; C10L 1/08; C10L 10/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models
Japanese Utility models and applications for Utility models

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

eKOMPASS (KIPO internal) & Keywords: heavy oil additive, oil soluble metallic compound, oxygen carrier, dispersant, lubricant, nonionic surfactant, detergent, dimethyl carbonate, dimethyl ether, complete combustion

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-1071204 B1 (LEE, Young Seo) 10 October 2011 See paragraphs [0013], [0030]; claims 1-3, 9, 17, 18.	1-10
Y	KR 10-0569899 B1 (HYUNDAI MOTOR COMPANY) 10 April 2006 See paragraphs [0011], [0018]-[0020], [0034]-[0038].	1-10
Y	US 5766272 A (LOZZI, O.) 16 June 1998 See column 1, lines 52-65; column 2, lines 14-50.	4
Y	US 4839094 A (MARSH, J. F. et al.) 13 June 1989 See example 1; claim 1.	7
A	KR 10-2009-0105925 A (INNOSPEC LIMITED) 07 October 2009 See the entire document.	1-10

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"G" document member of the same patent family

Date of the actual completion of the international search

09 NOVEMBER 2016 (09.11.2016)

Date of mailing of the international search report

10 NOVEMBER 2016 (10.11.2016)

Name and mailing address of the ISA/KR


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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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