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(54) Title: POLYALKYLENE GLYCOL BASE OIL FOR REDUCING NOX IN GAS FUELED COMBUSTION ENGINES

(57) Abstract: The present invention relates to a use of a polyalkylene glycol based lubricant in a gas fueled combustion engine for reducing the NOx emission of the gas fueled combustion engine. The present invention relates to a method for reducing the NOx emission of a gas fueled combustion engine comprising the step of lubricating the gas fueled combustion engine with a polyalkylene glycol based lubricant.

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Polyalkylene glycol base oil for reducing NOx in gas fueled combustion engines

The present invention relates to a use of a polyalkylene glycol based lubricant in a gas fueled combustion engine for reducing the NOx emission of the gas fueled combustion engine. The present invention relates to a method for reducing the NOx emission of a gas fueled combustion engine comprising the step of lubricating the gas fueled combustion engine with a polyalkylene glycol based lubricant.

Increasingly gas, such as hydrogen, is also being discussed as a potential fuel for combustion engines in future. Wherever battery-electric engines reach their limits, gas such as hydrogen as an energy carrier is discussed. In the public hydrogen is often discussed with fuel cells for energy conversion into electricity. However, in terms of cost, dynamics and durability gas fueled engines are often the better alternative.

A drawback of gas-fueled engines can be high emission, such as NOx.

WO2008/048909 discloses a hydrogen fueled combustion engine with a special exhaust gas recirculation EGR to address the NOx emissions.

Object of the present invention was to find a way to reduce NOx emission in gas fueled combustion engines.

The object was solved by a use of a polyalkylene glycol based lubricant in a gas fueled combustion engine for reducing the NOx emission of the gas fueled combustion engine.

The object was also solved by a method for reducing the NOx emission of a gas fueled combustion engine comprising the step of lubricating the gas fueled combustion engine with a polyalkylene glycol based lubricant.

The **NOx emissions** are typically produced in a combustion chamber of the gas fueled combustion engine by chemical interactions between atmospheric nitrogen (N₂) and oxygen (O₂). Nitric oxide (NO) is often formed in the highest concentrations, but other NOx compounds such as NO₂ are also formed in lower quantities. The NOx emission preferably refers to the sum of the emission of NO and NO₂.

The NOx emission can be analyzed by Fourier transform infrared spectroscopy (FTIR).

Various FTIR analyzers for NO_x analysis are commercially available. FTIR usually measures the entire infrared spectrum to identify the unique chemical fingerprint of a wide variety of gases. The NO_x can be analyzed directly from the source with no sample preparation. Preferably, the NO_x is analyzed by FTIR of the sum of NO and NO₂.

The NO_x emission is usually analyzed in the exhaust of the gas fueled combustion engine.

The NO_x emission is preferably analyzed in the exhaust of the gas fueled combustion engine after passing a catalytic exhaust gas aftertreatment system.

Usually, the NO_x emission of the gas fueled combustion engine is **reduced compared** to a mineral oil based lubricant in the gas fueled combustion engine.

Usually, the NO_x emission of the gas fueled combustion engine is reduced compared to a mineral oil based lubricant in the gas fueled combustion engine, where the polyalkylene glycol based lubricant and the mineral oil based lubricant have the same kinematic viscosity at 100 °C, such as 11 mm²/s.

The mineral oil based lubricant has usually a SAE (Society of Automotive Engineers) engine oil grade of W 30, preferably 10 W 30.

The mineral oil based lubricant has usually a kinematic viscosity at 100 °C of about 11 mm²/s.

The NO_x emission is usually reduced by at least 100 ppm, preferably at least 200 ppm, and in particular at least 300 ppm compared to the mineral oil based lubricant.

The NO_x emission is usually reduced at least 20 %, preferably at least 30 %, and in particular at least 40 % compared to the mineral oil based lubricant.

A **gas fueled combustion engine** and especially a hydrogen fueled combustion engine is commercially available from various companies and in various sizes. The gas fueled combustion engine can be stationary (e.g. in a heat and power plant) or mobile (e.g. in a ship, plane, tractor, harvester-thresher, or truck). The gas fueled combustion engine may have a port fuel injection or a direct injection.

The gas fueled combustion engine is usually fueled with a gas comprising methane, natural gas, hydrogen, or mixtures thereof. The gas fueled combustion engine is preferably fueled with a gas comprising methane or hydrogen, or mixtures thereof.

In a preferred form the gas fueled combustion engine is fueled with **hydrogen**, which may contain at least 90 wt%, preferably at least 95 wt%, and in particular at least 97 wt% of hydrogen.

In another preferred form the gas fueled combustion engine is fueled with **hydrogen mixtures**, such as a mixture of hydrogen and hydrocarbons. In another preferred form the gas fueled combustion engine is fueled with a mixture of hydrogen and hydrocarbons. Suitable mixtures of hydrogen and hydrocarbons are a mixture of hydrogen and diesel, or a mixture hydrogen and natural gas, where the latter is preferred. The hydrogen mixtures may contain at least 2 wt%, preferably at least 5 wt% and in particular at least 8 wt% of hydrogen.

In another preferred form the gas fueled combustion engine is fueled with **natural gas**, which may contain at least 50 wt%, preferably at least 70 wt%, and in particular at least 80 wt% of methane.

In another preferred form the gas fueled combustion engine is fueled with **methane**, which may contain at least 90 wt%, preferably at least 95 wt%, and in particular at least 98 wt% of methane.

The **polyalkylene glycol based lubricant** may comprise one or more polyalkylene glycols. Preferably, the polyalkylene glycol based lubricant comprises at least two polyalkylene glycols, which optionally differ in their kinematic viscosity at 100 °C.

The polyalkylene glycol based lubricant comprises usually at least 50 wt%, preferably at least 70 wt%, and in particular at least 85 wt% of the polyalkylene glycol. In case the polyalkylene glycol based lubricant comprises at least two polyalkylene glycols, then these amounts relate to the total sum of the at least two polyalkylene glycols.

The polyalkylene glycol based lubricant comprises usually below 3 wt%, preferably below 1 wt% and in particular below 0.1 wt% of a mineral oil, such as API Group I, II or III base oils. In another form the polyalkylene glycol based lubricant is free of a mineral oil, such as API Group I, II or III base oils.

The polyalkylene glycol in the polyalkylene glycol based lubricant is usually an **alkoxylated alcohol**, preferably an ethoxylated and propoxylated C₁-C₂₀ alkanol or C₂-C₂₀ alkandiol, and in particular an ethoxylated and propoxylated C₁-C₈ alkanol.

Suitable alkoxylated alcohols are ethoxylated, ethoxylated and propoxylated, or ethoxylated and butoxylated. Preferably, alkoxylated alcohols are ethoxylated and propoxylated.

The alkoxylated alcohols may have a number average molecular weight Mn in the range from 400 to 10 000 Da, preferably from 700 to 3000 Da, and in particular from 1000 to 1500 Da. The Mn may be calculated based on the hydroxy number.

The alkoxylated alcohol may contain at least 20 wt%, preferably at least 30 wt% and in particular at least 40 wt% of ethylene oxide units.

The alkoxylated alcohol may contain 20 to 80 wt% ethylene oxide units, and 80 to 20 wt% of propylene oxide units. The alkoxylated alcohol preferably contains 30 to 70 wt% ethylene oxide units, and 70 to 30 wt% of propylene oxide units. In particular, the alkoxylated alcohol contains 40 to 60 wt% ethylene oxide units, and 60 to 40 wt% of propylene oxide units. The wt% of the ethylene oxide and propylene oxide usually sum up to 100 wt%

The alkoxy groups in the alkoxylated alcohol may be random or in block sequence. Preferably the alkoxy groups (e.g. the ethoxy and propoxy groups) in the alkoxylated alcohol are random sequence.

The polyalkoxylate chain of the alkoxylated (e.g. ethoxylated and propoxylated) alcohols may be terminated by a hydroxy group or a C₁ to C₄ alkyl, wherein the hydroxy group is preferred.

Suitable alcohol units in the alkoxylated alcohol are linear or branched C₁-C₂₀ alkanol or C₂-C₂₀ alkandiol, preferably C₁-C₈ alkanol or C₂-C₈ alkandiol, and in particular C₁-C₆ alkanol or C₂-C₆ alkandiol.

In another preferred form the alcohol units in the alkoxylated (e.g. ethoxylated and propoxylated) alcohol are linear or branched C₁-C₁₂ alkanol, preferably C₁-C₆ alkanol, and in particular C₁-C₄ alkanol.

The alcohol units in the alkoxylated alcohol may be a technical mixture of various chain lengths and isomers.

The polyalkylene glycol based **lubricant** may have a kinematic viscosity at 40 °C in the range from 10-300 mm²/s, preferably from 20-150 mm²/s, and in particular from 35-80 mm²/s.

The polyalkylene glycol based lubricant may have a kinematic viscosity at 100 °C in the range from 3-80 mm²/s, preferably from 5-40 mm²/s, and in particular from 8-20 mm²/s.

The polyalkylene glycol based lubricant may have a kinematic viscosity at 100 °C of below 20 mm²/s, preferably below 15 mm²/s, and in particular below 13 mm²/s.

The polyalkylene glycol based lubricant may have a viscosity index at 100 °C of at least 150, preferably at least 180, and in particular at least 200.

The kinematic viscosity may be determined according to ASTM D445.

The polyalkylene glycol based lubricant may have a pour point of below -30 °C, preferably below -40 °C, and in particular below -45 °C. The pour point may be determined according to ASTM D 97.

The polyalkylene glycol based lubricant may be soluble in water (e.g. at 20 °C), such as at least 10 g/l, preferably at least 100 g/l.

Lubricants usually refers to composition which are capable of reducing friction between surfaces (preferably metal surfaces), such as surfaces of mechanical devices.

The polyalkylene glycol based lubricant may comprise **lubricant additives**, such as polymeric thickeners, corrosion inhibitors, detergents, dispersants, defoamer, dyes, wear protection additives, extreme pressure agents, anti-wear additives, friction modifiers, metal deactivators, pour point depressants, demulsifiers.

The polyalkylene glycol based lubricant may comprise up to 20 wt%, preferably up to 15 wt% and in particular up to 10 wt% of the lubricant additive.

The polyalkylene glycol based lubricant is preferably free of a viscosity improver.

The polyalkylene glycol based lubricant is preferably free of a silicon defoamer.

Suitable (polymeric) **thickeners** include, but are not limited to, polyisobutenes (PIB), oligomeric co-polymers (OCPs), polymethacrylates (PMAs), copolymers of styrene and butadiene, or high viscosity esters (complex esters).

Corrosion inhibitors may include various oxygen-, nitrogen-, sulfur-, and phosphorus-containing materials, and may include metal-containing compounds (salts, organometallics, etc.) and nonmetal-containing or ashless materials. Corrosion inhibitors may include, but are not limited to, additive types such as, for example, hydrocarbyl-, aryl-, alkyl-, arylalkyl-, and alkylaryl versions of detergents (neutral, overbased), sulfonates, phenates, salicylates, alcoholates, carboxylates, salixarates, phosphites, phosphates, thiophosphates, amines, amine salts, amine phosphoric acid salts, amine sulfonic acid salts, alkoxylated amines, etheramines, polyetheramines, amides, imides, azoles, diazoles, triazoles, benzotriazoles, benzothiadoles, mercaptobenzothiazoles, tolyltriazoles (TTZ-type), heterocyclic amines, heterocyclic sulfides, thiazoles, thiadiazoles, mercaptothiadiazoles, dimercaptothiadiazoles (DMTD-type), imidazoles, benzimidazoles, dithiobenzimidazoles, imidazolines, oxazolines, Mannich reactions products, glycidyl ethers, anhydrides, carbamates, thiocarbamates, dithiocarbamates, polyglycols, etc., or mixtures thereof.

Detergents include cleaning agents that adhere to dirt particles, preventing them from attaching to critical surfaces. Detergents may also adhere to the metal surface itself to keep it clean and prevent corrosion from occurring. Detergents include calcium alkylsalicylates, calcium alkylphenates and calcium alkarylsulfonates with alternate metal ions used such as magnesium, barium, or sodium. Examples of the cleaning and dispersing agents which can be used include metal-based detergents such as the neutral and basic alkaline earth metal sulphonates, alkaline earth metal phenates and alkaline earth metal salicylates alkenylsuccinimide and alkenylsuccinimide esters and their borohydrides, phenates, salienius complex detergents and ashless dispersing agents which have been modified with sulphur compounds. These agents can be added and used individually or in the form of mixtures, conveniently in an amount within the range of from ≥ 0.01 to ≤ 1.0 % by weight in relation to the weight of the base stock; these can also be high total base number (TBN), low TBN, or mixtures of high/low TBN.

Dispersants are lubricant additives that help to prevent sludge, varnish and other deposits from forming on critical surfaces. The dispersant may be a succinimide dispersant (for example N-substituted long chain alkenyl succinimides), a Mannich dispersant, an ester-containing dispersant, a condensation product of a fatty hydrocarbyl monocarboxylic

acylating agent with an amine or ammonia, an alkyl amino phenol dispersant, a hydrocarbyl-amine dispersant, a polyether dispersant or a polyetheramine dispersant. In one embodiment, the succinimide dispersant includes a polyisobutylene-substituted succinimide, wherein the polyisobutylene from which the dispersant is derived may have a number average molecular weight of about 400 to about 5000, or of about 950 to about 1600. In one embodiment, the dispersant includes a borated dispersant. Typically, the borated dispersant includes a succinimide dispersant including a polyisobutylene succinimide, wherein the polyisobutylene from which the dispersant is derived may have a number average molecular weight of about 400 to about 5000. Borated dispersants are described in more detail above within the extreme pressure agent description.

Suitable **extreme pressure agent** is a sulfurcontaining compound. In one embodiment, the sulfur-containing compound may be a sulfurised olefin, a polysulfide, or mixtures thereof. Examples of the sulfurised olefin include a sulfurised olefin derived from propylene, isobutylene, pentene; an organic sulfide and/or polysulfide including benzyldisulfide; bis-(chlorobenzyl) disulfide; dibutyl tetrasulfide; di-tertiary butyl polysulfide; and sulfurised methyl ester of oleic acid, a sulfurised alkylphenol, a sulfurised dipentene, a sulfurised terpene, a sulfurised Diels-Alder adduct, an alkyl sulphenyl N'N dialkyl dithiocarbamates; or mixtures thereof. In one embodiment, the sulfurised olefin includes a sulfurised olefin derived from propylene, isobutylene, pentene or mixtures thereof. In one embodiment the extreme pressure additive sulfur-containing compound includes a dimercaptothiadiazone or derivative, or mixtures thereof. Examples of the dimercaptothiadiazone include compounds such as 2,5-dimercapto-1,3,4-thiadiazone or a hydrocarbyl-substituted 2,5-dimercapto-1,3,4-thiadiazone, or oligomers thereof. The oligomers of hydrocarbyl-substituted 2,5-dimercapto-1,3,4-thiadiazone typically form by forming a sulfur-sulfur bond between 2,5-dimercapto-1,3,4-thiadiazone units to form derivatives or oligomers of two or more of said thiadiazone units. Suitable 2,5-dimercapto-1,3,4-thiadiazone derived compounds include for example 2,5-bis(tert-nonyldithio)-1,3,4-thiadiazone or 2-tert-nonyldithio-5-mercapto-1,3,4-thiadiazone. The number of carbon atoms on the hydrocarbyl substituents of the hydrocarbyl-substituted 2,5-dimercapto-1,3,4-thiadiazone typically include 1 to 30, or 2 to 20, or 3 to 16. Extreme pressure additives include compounds containing boron and/or sulfur and/or phosphorus. The extreme pressure agent may be present in the lubricant compositions at 0 wt.-% to about 20 wt.-%, or at about 0.05 wt.-% to about 10.0 wt.-%, or at about 0.1 wt.-% to about 8 wt.-% of the lubricant composition.

Examples of **anti-wear additives** include organo borates, organo phosphites such as didodecyl phosphite, organic sulfur-containing compounds such as sulfurized sperm oil or sulfurized terpenes, zinc dialkyl dithiophosphates, zinc diaryl dithiophosphates, phosphosulfurized hydrocarbons and any combinations thereof.

Friction modifiers may include metal-containing compounds or materials as well as ashless compounds or materials, or mixtures thereof. Metal-containing friction modifiers include metal salts or metalligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have lowash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivative of alcohols, polyols, glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles, triazoles, and other polar molecular functional groups containing effective amounts of O, N, S, or P, individually or in combination. In particular, Mo-containing compounds can be particularly effective such as for example Mo-dithiocarbamates, Mo(DTC), Mo-dithiophosphates, Mo(DTP), Mo-amines, Mo (Am), Mo-alcoholates, Mo alcohol-amides, and the like.

Ashless friction modifiers may also include lubricant materials that contain effective amounts of polar groups, for example, hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hydrocarbyl groups containing effective amounts of O, N, S, or P, individually or in combination. Other friction modifiers that may be particularly effective include, for example, salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long-chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, and the like. In some instances, fatty organic acids, fatty amines, and sulfurized fatty acids may be used as suitable friction modifiers. Examples of friction modifiers include fatty acid esters and amides, organo molybdenum compounds, molybdenum dialkylthiocarbamates and molybdenum dialkyl dithiophosphates.

Suitable **metal deactivators** include benzotriazoles and derivatives thereof, for example 4- or 5-alkylbenzotriazoles (e.g. triazole) and derivatives thereof, 4,5,6,7-tetrahydrobenzotriazole and 5,5'-methylenebisbenzotriazole; Mannich bases of benzotriazole or triazole, e.g. 1-[bis(2-ethyl-hexyl) aminomethyl] triazole and 1-[bis(2- ethylhexyl)

aminomethyl)benzotriazole; and alkoxy-alkylbenzotriazoles such as 1-(nonyloxymethyl)benzotriazole, 1-(1-butoxyethyl) benzotriazole and 1-(1-cyclohexyloxybutyl) triazole, and combinations thereof. Additional non-limiting examples of the one or more metal deactivators include 1,2,4-triazoles and derivatives thereof, for example 3-alkyl(or aryl)-1, 2,4-triazoles, and Mannich bases of 1,2,4-triazoles, such as 1-[bis(2-ethylhexyl) aminomethyl]-1, 2,4-triazole; alkoxyalkyl-1, 2,4-triazoles such as 1-(1-butoxyethyl)-1, 2,4-triazole; and acylated 3-amino-1, 2,4-triazoles, imidazole derivatives, for example 4,4'-methylenebis(2-undecyl-5-methylimidazole) and bis[(N-methyl)imidazol-2-yl]-carbinol octyl ether, and combinations thereof. Further non-limiting examples of the one or more metal deactivators include sulfur-containing heterocyclic compounds, for example 2-mercaptobenzothiazole, 2,5-dimercapto-1, 3,4-thiadiazole and derivatives thereof; and 3,5-bis[di(2-ethylhexyl) aminomethyl]-1, 3,4-thiadiazolin-2-one, and combinations thereof. Even further non-limiting examples of the one or more metal deactivators include amino compounds, for example salicylidenepropylenediamine, salicylamino-guanidine and salts thereof, and combinations thereof. The one or more metal deactivators are not particularly limited in amount in the composition but are typically present in an amount of from about 0.01 to about 0.1, from about 0.05 to about 0.01, or from about 0.07 to about 0.1, wt.-% based on the weight of the composition. Alternatively, the one or more metal deactivators may be present in amounts of less than about 0.1, of less than about 0.7, or less than about 0.5, wt.-% based on the weight of the composition.

Pour point depressants (PPD) include polymethacrylates, alkylated naphthalene derivatives, and combinations thereof. Commonly used additives such as alkylaromatic polymers and polymethacrylates are also useful for this purpose. Typically, the treat rates range from ≥ 0.001 wt.-% to ≤ 1.0 wt.-%, in relation to the weight of the base stock.

Demulsifiers include trialkyl phosphates, and various polymers and copolymers of ethylene glycol, ethylene oxide, propylene oxide, or mixtures thereof.

Examples

The following polyalkylene glycol based lubricant ("PAG Oil A") was tested:

44.6 wt% alkoxylated alcohol (butanol statistically ethoxylated and propoxylated, 50/50 wt%),
KV40 135-155 mm²/s (ASTM D445).

44.5 wt% alkoxylated alcohol (butanol statistically ethoxylated and propoxylated, 50/50 wt%),
KV40 18-22 mm²/s (ASTM D445).

- 0.5 wt% silicon-free defoamer (polyethyleneoxide-polypropyleneoxide-polyethyleneoxide (EO-PO-EO) triblock polymer, molar mass about 2500-2800, molar mass of PO block about 2200-2500 g/mol, amount of PE block in triblock polymer about 10%.
- 10.4 w% additive package with solubilizer, antioxidants and corrosion protection.

This polyalkylene glycol based lubricant had a KV40 = 52 mm²/s, KV100 = 11 mm²/s, VI = 215, pour point -54 °C. It is classified according as 10 W 30 engine oil. It is free of a silicon defoamer and free of a viscosity index improver.

As comparative mineral oil based lubricant was tested a commercial available Group III mineral oil based engine oil from Motorex®, Switzerland. This mineral oil based lubricant had a KV40 = 76 mm²/s, KV100 = 11 mm²/s, VI = 139, pour point -27 °C. It is classified according as 15 W 30 engine oil.

Example 1

The emission test were made on a commercially available combined heat and power plant Vitobloc® 200 Type EM 9/20 (Viessmann, Germany) with a 3 cylinder gas combustion engine (Toyota, 952 cm³ displacement), no turbocharge, lambda = 1, stationary at 1500 rpm, an electrical power of 8.5 kW, a thermal power of 20.1 kW, a torque 54,2 Nm serial engine control (ecu), and indicated mean effective preassure (pme) 6.8 bar.

The engine had a port fuel injection, was water-cooled and lubricated by a circulatory lubrication. The exhaust system had a controlled 3 way catalytic converter. The CO and the NOx emission in the exhaust (about 500-550 °C) was determined after the catalytic converter by FTIR.

This combustion engine was run at constant load and was fueled with a mixture of hydrogen and methane in a ratio of 1:9.

This combustion engine was lubricated either with the above polyalkylene glycol based lubricant PAG Oil A or for comparison with the mineral oil based lubricant.

The emission of CO and NOx was determined in both cases after 85 h operating time of the combustion engine for a period of 240 seconds, and the average value determined.

The CO emission of the polyalkylene glycol based lubricant and the comparative mineral oil based lubricant were on a similar level of about 100 ppm.

The NO_x emission of the polyalkylene glycol based lubricant was about 395 ppm, whereas the comparative mineral oil based lubricant resulted in NO_x emission of about 850 ppm.

The engine block was visually analyzed after 300 h operating time with the polyalkylene glycol based lubricant. Now significant wear was found.

Example 2

The combustion engine described in Example 1 was used. This combustion engine was lubricated either with the above polyalkylene glycol based lubricant PAG Oil A or for comparison with the mineral oil based lubricant of Example 1.

In test run 2A the combustion engine was fueled with CH₄ for 100 hours.

In test run 2B the combustion engine was first fueled with CH₄ / H₂ (ratio 9/1) for 28 hours, followed by CH₄ / H₂ (ratio 8/2) for 100 hours.

Various parameters of the polyalkylene glycol based lubricant were analyzed before and after the test run 2A and 2B. The results are shown in Table 1.

The data showed that the polyalkylene glycol based lubricant had excellent stability in an gas fueled combustion engine: No wear of friction was observed as determined by the concentration of abrasive metals in the lubricant; the water concentration did not increase; the kinematic viscosity, the VI and the acid number remained constant.

Table 1: Analytical data of the polyalkylene glycol based lubricant

Parameter	Analytical Method	before tests	Test Run 2A	Test Run 2B
Wear of friction (sum of Fe, Cr, Sn, Al, Ni, Pb, Mo, Mn, Si)	ICP acc. DIN 41399 or ASTM D 5185	0 ppm	0 ppm	0 ppm
Water concentration	Karl Fischer titration	0.67 %	0.63 %	0.31 %
Kinematic viscosity at 40 °C	DIN 51659-3, DIN ISO 2909, ASTM D2270, ASTM D7279	51.7 mm ² /s	53.9 mm ² /s	51.9 mm ² /s
Kinematic viscosity at 100 °C	DIN 51659-3, DIN ISO 2909, ASTM D2270, ASTM D7279	11.1 mm ² /s	11.6 mm ² /s	11.2 mm ² /s

Viscosity index	DIN 51659-3, DIN ISO 2909, ASTM D2270, ASTM D727	215	217	218
Acid number [mg KOH/g]	ASTM D664	0.2	0.22	<0.1

Example 3

The scuffing performance was tested to evaluate the scuffing limit of piston ring – cylinder liner – oil tribosystem in dependency of temperature.

The test procedure is based on Obert et. al., Tribology International 94 (2016) 306 – 314: The scuffing limit reacts very sensitive on oil amount and oil temperature (viscosity). The scuffing limit is usually only valid for one oil temperature. The load range was 50 - 400 N, 4 mm stroke at 20 Hz, and oil lubrication was 0.1 µl/min. The tests were performed according to a staircase method: In case of scuffing, the load was decreased, in case of no scuffing, the load was increased. If the load exceeded 400 N, then the temperature was increased by 10 K. If the load was below 50 N, then the temperature was reduced by 10 K. As a result the mean load value for one temperature level was obtained.

The used specimens were:

Cylinder liner: Daimler OM471, Stratum (Ø 132)

Piston ring variants: Volvo HDE13, MIP 230 (PVD)

The polyalkylene glycol based lubricant PAG Oil A was used as described above. For comparison a commercial oil 0W-20 diesel oil was used with a kinematic viscosity at 40 °C of approx. 40 mm²/s and a kinematic viscosity at 100 °C of approx. 8 mm²/s.

The results are summarized in Tables 2 and 3: Table 2 shows that the PAG oil was better compared to the Diesel engine oil with regard to the scuffing limit. Table 3 shows that the PAG oil was better compared to the Diesel engine oil with regard to the friction coefficient, which indicates a better fuel economy.

Table 2:

	Scuffing limit at 200 °C
PAG Oil A	>= 400 N
Diesel engine oil	122 N

Table 3: Friction coefficient at 200 °C)

	After 30 min	End of test
Diesel engine oil	0.153	0.197
PAG Oil A	0.084	0.057

Claims

1. A use of a polyalkylene glycol based lubricant in a gas fueled combustion engine for reducing the NO_x emission of the gas fueled combustion engine.
2. The use according to claim 1 where the polyalkylene glycol based lubricant comprises at least two polyalkylene glycols.
3. The use according to claim 1 or 2 where the polyalkylene glycol based lubricant comprises at least 50 wt% of the polyalkylene glycol.
4. The use according to any of claims 1 to 3 where the polyalkylene glycol is an alkoxyated alcohol.
5. The use according to claim 4 where the alkoxyated alcohol comprises at least 20 wt% of ethylene oxide units.
6. The use according to claim 4 or 5 where the alkoxyated alcohol is an ethoxylated and propoxylated C₁-C₂₀ alkanol or an ethoxylated and propoxylated C₂-C₂₀ alkandiol.
7. The use according to any of claims 1 to 6 where the polyalkylene glycol based lubricant is soluble in water.
8. The use according to any of claims 1 to 7 where the polyalkylene glycol based lubricant has a viscosity index at 100 °C of at least 180.
9. The use according to any of claims 1 to 8 where the polyalkylene glycol based lubricant has a pour point of below -30 °C.
10. The use according to any of claims 1 to 9 where the NO_x concentration is analyzed by Fourier transform infrared spectroscopy.
11. The use according to any of claims 1 to 10 where the NO_x emission is reduced compared to a mineral oil based lubricant in the gas fueled combustion engine.

12. The use according to any of claims 1 to 11 where the NO_x emission is reduced at least 20 % compared to a mineral oil based lubricant.
13. The use according to any of claims 1 to 12 where the NO_x emission is reduced by at least 100 ppm compared to the mineral oil based lubricant.
14. The use according to any of claims 1 to 13 where the gas fueled combustion engine is fueled with a gas comprising methane, natural gas, hydrogen, or mixtures thereof.
15. A method for reducing the NO_x emission of a gas fueled combustion engine comprising the step of lubricating the gas fueled combustion engine with a polyalkylene glycol based lubricant.
16. The method according to claim 15 where the alkoxylated alcohol is an ethoxylated and propoxylated C₁-C₂₀ alkanol or an ethoxylated and propoxylated C₂-C₂₀ alkandiol.
17. The method according to claim 15 or 16 where the polyalkylene glycol based lubricant is soluble in water.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066910

A. CLASSIFICATION OF SUBJECT MATTER INV. C10M107/34 ADD.		
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) C10M		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 3 053 049 A1 (TOTAL MARKETING SERVICES [FR]) 29 December 2017 (2017-12-29) page 1, lines 4-6; claim 1 page 11, line 31 - page 12, line 1 page 15, line 15 - line 16 -----	1 - 17
X	CN 106 609 171 A (CHINA PETROLEUM & CHEM CORP) 3 May 2017 (2017-05-03)	15, 16
A	abstract; claims 1-3 & DATABASE WPI Week 201742 Thomson Scientific, London, GB; AN 2017-290098 & CN 106 609 171 A (SINOPEC CORP) 3 May 2017 (2017-05-03) abstract -----	1 - 14, 17
☐ 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 "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "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 "&" document member of the same patent family		
Date of the actual completion of the international search 10 July 2024		Date of mailing of the international search report 29/07/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Pöllmann, Klaus

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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			WO 2018002175 A1	04-01-2018

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