A fuel emulsion having a three-phase composition, based on at least one hydrocarbon and on water, the fuel emulsion including: a continuous hydrocarbon phase; a phase of cavitation water vapor bubbles dispersed within the continuous hydrocarbon phase; and a phase of water droplets dispersed within the continuous hydrocarbon phase, wherein the emulsion is obtainable by vibroacoustic processing.
FUEL EMULSION AND METHOD OF PREPARATION

FIELD AND BACKGROUND OF THE INVENTION

[0001] The present invention relates to the field of production of emulsion fuel compounds consisting of a water emulsion and a single hydrocarbon or a mixture of hydrocarbons, such as diesel fuel, automotive fuel, furnace fuel, biofuel, oil, kerosene, alcohol, and so forth. The invention is also related to a method for production of stable water-fuel emulsions of the “water-in-fuel” emulsion type without stabilization of the disperse phase by means of surface active compounds or emulsifiers.

BACKGROUND OF THE INVENTION

[0002] Experts have devoted particular attention in recent years to solving tasks concerning the formation of fuel compounds, especially motor fuel, that include petroleum substitutes for lowering the involved cost and restricting the pollution of the environment. It has been found that water constitutes a valuable additive to or partial substitute for hydrocarbons in some fuels. Water, as a cheap and nontoxic liquid, can reduce fuel consumption reduce exhausts of visible and invisible substances.

[0003] The following terms are defined in the specification and in the claims which follow:

[0004] “water-in-fuel” is intended to mean any emulsion of water in fuel wherein the overall volumetric fraction of water in the water/fuel mixture is approximately 50% or less;

[0005] “fuel-in-water” is intended to mean any emulsion of fuel in water wherein the overall volumetric fraction of water in the water/fuel mixture is over approximately 50%;

[0006] “WFE” is intended to mean a “water-fuel emulsion” derived from embodiments of the present invention without regard to a specific ratio of water and fuel;

[0007] “fuel emulsion” is intended to mean WFE.

[0008] Notwithstanding the obvious advantages of using water as an additive, no single water-in-fuel or fuel-in-water has yet to find wide industrial application. One reason for this is due to serious problems regarding the stability of emulsions in a fuel tank and to conditions of subsequent transportation and emulsion utilization.

[0009] Efforts to solve the problem of improving the stability of fuel emulsions have been directed mainly at improving the chemical composition of emulsifying systems in the form of surfactants and/or additives.

[0010] One example of the difficulties associated with the use of emulsifying systems, is as described by Lepain, in French patent application 80 24146 (publication No. 2 470 153), whose disclosure is incorporated herein by reference. Lepain describes an emulsified diesel fuel containing hydrocarbons, water, alcohol (methanol, ethanol) and an emulsifying system composed of sorbitanmonooleate and ethoxilated nonylphenol. The concentration of the emulsifying system in the emulsion accounts for 3% to 10% of the volume, whereas the stability of this water-alcohol-hydrocarbon emulsion falls short of satisfactory. After storage of the emulsion for 72 hours, which corresponds to a typical period of fuel storage in a vehicle, segregation of phases between hydrocarbons and the water-alcohol mixture begins. The segregated phase of hydrocarbons can account for up to 3% of the emulsion volume after a storage period of 72 hours. Within a few days of storage the phase segregation in the fuel emulsion described by Lepain becomes pronounced enough to interfere with vehicle operation in normal use conditions.

[0011] Moreover, the presence of expensive components of the emulsifying system of such emulsions is disadvantageous both economically and functionally for engines using such emulsions. Mekonen, in U.S. Pat. No. 4,877,414, whose disclosure is incorporated herein by reference, describes emulsification of a motor fuel with various additives such as an emulsifying system composed of sorbitan sesquioleate, sorbitan monoleate and polyoxyethylene ether (6 EO) of dodecyl alcohol. Mekonen notes that the total amount of all additives should be about 2.1%. Other additives that can be used separately from the emulsifying system comprise mono/alphaolefin (decene-1), 2-methoxy ethanol, toluene, alkyl benzenes, and calcium hydroxide.

[0012] Such compositions as noted hereinabove are both expensive and extremely complex, owing to the large number of additives. Moreover, the emulsified fuel, as described by Mekonen, is not particularly stable, especially at low temperatures, with phase segregation taking place within one hour. This trend is further accelerated at temperatures below 5°C. Such emulsions, stored in a vehicle fuel tank in operation in winter conditions, could be very problematic.

[0013] For obvious reasons of compatibility of components located between the fuel tank and the engine fuel supply system it is preferable to use a fuel having a dispersion medium very similar or identical to that for which the components and fuel supply system were designed. In the case of emulsified motor fuels, where the dispersion medium is water, corrosion of metal surfaces and/or accelerated wear of elastomeric materials may occur.

[0014] Moreover, combustion of water-in-fuel emulsions is preferable over fuel-in-water since the rapid evaporation of water droplets dispersed in the fuel improves dispersion of hydrocarbons in the combustion chamber. Such water-in-fuel emulsions are described by Haupais et al. in Patent Application WO 97/54969 and by Magnin et al. in WO 00/34149, whose disclosures are incorporated herein by reference. However, the presence of a surfactant in the border envelope of the phase of internal water droplets during fuel emulsion transport causes the water phase to coalesce, thereby substantially reducing dispersion of hydrocarbons in the combustion chamber. A preferable criterion for the quality of the fuel emulsion described by Haupais is the size of water droplets of the dispersion phase. However, the applied emulsifying systems described by Haupais yield fuel emulsions where the average size of water droplets of the dispersion phase is less than or equal to 3 microns.

[0015] The use of emulsifying systems in fuel emulsions increases overall costs and exacerbates ecologic properties of gas exhaust from the working engine.

[0016] The prior art noted hereinabove describe an emulsified fuel and methods for its industrial preparation where the disperse phase in the emulsion is stabilized by the use of expensive emulsifying surfactant systems. However, substantial improvements to the operating characteristics of emulsified fuels can be made, such as: improved stability; reduction of the level of visible and invisible pollutants; reduction of fuel consumption; and overall cost reductions.
The above prior art review underscores the need for emulsified fuels that possess improved operating characteristics, physical-chemical stability (i.e. no segregation into phases), minimal polluting effect, and favorable cost and expense characteristics. Furthermore, there is a need to prepare such fuels without the addition of surfactants or other emulsifying systems or additives in the fuel composition.

SUMMARY OF THE INVENTION

The present invention is a fuel emulsion based on hydrocarbon and water without the addition of surfactants or other emulsifying systems or additives in the fuel composition, and a method for the preparation of such a fuel emulsion.

According to the teachings of the present invention there is provided a fuel emulsion having a three-phase composition, based on at least one hydrocarbon and on water, the fuel emulsion comprising: a continuous hydrocarbon phase; a phase of cavitational water vapor bubbles dispersed within the continuous hydrocarbon phase; and a phase of water droplets dispersed within the continuous hydrocarbon phase, wherein the emulsion is obtainable by vibroacoustic processing. Preferably, the volumetric proportion of cavitational water vapor bubbles ranges from 0.25% to less than 1.5%. Most preferably, the average diameter of water droplets is less than or substantially equal to 1 micron.

Typically, the average diameter of cavitational water vapor bubbles is less than or substantially equal to 0.2 microns. Most typically, the hydrocarbon includes at least one chosen from the list including: diesel oil, heavy oil; furnace oil; biofuel; gasoline; kerosene; and alcohol. Preferably, the volume ratio of hydrocarbon to water ranges from substantially 90:10 to substantially 70:30.

According to the teachings of the present invention there is further provided a method of preparing a fuel emulsion having a three-phase composition, based on at least one hydrocarbon and on water, involving the steps of mixing the at least one hydrocarbon and water; and processing the mixture of hydrocarbon and water in a vibroacoustic mixer to yield a three-phased emulsion having a continuous phase of the hydrocarbon and respective dispersed phases of water droplets and cavitational water vapor bubbles. Preferably, the average diameter of the water droplets is less than or approximately equal to 1 micron. Most preferably, the average size of the cavitational water vapor bubbles is less than or approximately equal to 0.2 microns. Typically, the cavitational water bubble phase in the emulsion ranges from substantially less than 1.5% to greater than 0.25% by volume. Most typically, mixing the at least one hydrocarbon and water is performed with a volumetric ratio of hydrocarbon to water ranging from substantially 90:10 to substantially 70:30. Preferably, the hydrocarbon includes at least one chosen from the list including: diesel oil, heavy oil; furnace oil; biofuel; gasoline; kerosene; and alcohol.

FIG. 2 is a flow diagram showing the steps of the preparation of the fuel emulsion of FIG. 1, in accordance with embodiments of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is a fuel emulsion based on hydrocarbon and water without the addition of surfactants or other emulsifying systems or additives in the fuel composition, and a method for the preparation of such a fuel emulsion.

Reference is now made to FIG. 1, which is a photomicrograph presentation of the structure of a three-phase fuel emulsion system 10, in accordance with embodiments of the present invention. Three-phase fuel emulsion system 10 comprises a continuous hydrocarbon phase 12, a disperse phase of water droplets 13, and a disperse phase of cavitational water vapor bubbles 14. The distribution of disperse phase of water droplets 13 and disperse phase of the cavitation water vapor bubbles 14 is obtained by vibroacoustic treatment of the mixture of the emulsion components, namely: hydrocarbons and water.

The presence of the additional phase of cavitation water vapor bubbles 14 in the water-fuel emulsion imparts additional enhanced heat-exchange properties on the fuel during its combustion owing to properties of the bubbles, which includes the cavitation power of bubbles during their collapse. As the water vapor cavitation bubbles collapse, they provide conditions for substantial heat exchange, yielding additional detonation energy to the fuel during its combustion.

In a preferred embodiment of the present invention, disperse phase of cavitational water vapor bubbles 14 has a volumetric composition of three-phase emulsion system 10 ranging from 0.25% to 1.5%.

As noted hereinabove, emulsion system 10 is the product of vibroacoustic processing of the mixture constituents, namely hydrocarbons and water. Vibroacoustic processing of the hydrocarbon and water components ensures formation of stable discrete phases of water droplets and cavitation water vapor bubbles within a broad range of droplet and bubble size, yielding a reduction of the average bubble size without the addition of surfactants or any emulsifiers. This, in turn, serves to substantially achieve a stable and uniform distribution of water droplets and cavitation water vapor bubbles in the continuous phase of the hydrocarbon of the fuel emulsion. Emulsion stability is due to the discrete droplet and cavitation water vapor bubbles being reduced to a size where the interface between water droplets and continuous hydrocarbon phase 12 gives rise to surface tension forces that prevent the coalescence a disperse phase of water droplets 13, whereas the surface tension of the cavitation steam bubbles generates uniformly distributed equal-sense charges resulting from ions contained in the continuous hydrocarbon phase 12. Coulomb repulsion forces prevent the water vapor bubbles from coalescing.

In a preferred embodiment, the average diameter of water droplets is less than or approximately equal to 1 microns, whereas the average diameter of cavitational water vapor bubbles is less than or approximately equal to 0.2 microns.

Embodiments of the present invention preferably include a volumetric proportion of water in emulsion ranging from about 90:10 to 70:30. The proportion of water in the
emulsion is selected according to the type and quality of the hydrocarbon, and the operating conditions of the emulsion used by the user.

[0032] The hydrocarbon of choice in embodiments of the fuel emulsion described hereinabove include: diesel fuel, fuel oil, furnace oil, biofuel, oil, kerosene, and alcohol.

[0033] Reference is now made to FIG. 2, which is a block diagram of a system 20 for preparing a water-fuel emulsion (WFE), in accordance with an embodiment of the present invention. System 20 includes a filter 21 and a vibroacoustic mixer 22. To obtain the WFE, hydrocarbon and water are introduced continuously, through filter 21 at a controlled volume under a given pressure, maintaining a water-to-WFE volumetric ratio of about 90:10 to 70:30. The water/fuel mixture is then fed into vibroacoustic mixer 22 for vibroacoustic processing, in continuous flow. The vibroacoustic mixer, alternatively called “vibromixer” produces a three-phase dispersed emulsion having a continuous phase of hydrocarbon and dispersed phases of water droplets and cavitation water vapor bubbles.

[0034] The vibromixer includes a steel body with inlet and outlet fittings (not shown in the figure) and a nozzle 24 near the inlet fitting. Downstream from nozzle 24 there is a hydrodynamic oscillator 26. Hydrodynamic oscillator 26 is designed to be operated to produce elastic vibrations in the water/fuel mixture, which enables dispersion of the water and the formation of an aqueous phase in an emulsifiable mixture comprising droplets having a size equal or less than 1 micron and the formation of cavitation water vapor bubbles having a size equal or less than 0.2 microns. Following treatment in the vibromixer, the WFE is outputted and supplied to the customer. Examples of configurations of hydrodynamic oscillator 26 are noted hereinbelow.

[0035] Examples of the hydrocarbon fuel used in system 20 to produce WFE include: diesel fuel, heavy oil 1, furnace oil, biofuel, oil, kerosene, and alcohol. In all cases, the obtained WFE represents a highly dispersed fuel with improved performance properties. Specific examples are given hereinbelow for WFE based on: gasoline B-91 for an M14P engine: diesel fuel for TUD5 Peugeot 106 engine; and heavy oil for MAN 58/6015 ship engine. In all cases embodiments of the current invention makes it possible to reduce the content of harmful compounds in exhaust gases of the WFE, as described hereinbelow.

Example 1

M14P Engine

[0036] The volumetric composition of the current WFE is 90% B-91 gasoline and 10% water. Cavitation water vapor bubbles in the emulsion are approximately 0.25% by volume, with an average diameter of 0.15-0.2 microns, and with water droplets having an average diameter of 0.4-0.7 microns. Storage time before phase separation is 45 days, at a temperature of 30° C.

[0037] The following table summarizes and contrasts performance of conventional B-91 gasoline versus the present WFE. A discussion of operating modes with the WFE used in the M14P engine follows.

<table>
<thead>
<tr>
<th>Toxic exhausts</th>
<th>B-91 gasoline</th>
<th>WFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0.8% by volume</td>
<td>0.37% by volume</td>
</tr>
<tr>
<td>CO</td>
<td>5.2% by volume</td>
<td>2.08% by volume</td>
</tr>
<tr>
<td>C</td>
<td>0.05 g/m³</td>
<td>0.025 g/m³</td>
</tr>
</tbody>
</table>

[0038] Nominal Operation Mode:

[0039] At capacity of 245 HP, fuel consumption, due to the use of WFE, decreases by 11.9 kg/hour, meaning a savings of 14%.

[0040] Cruising Operation Mode:

[0041] At capacity of 180 HP, fuel consumption, due to the use of WFE, decreases by 9 kg/hour, meaning a savings of 16%.

Example 2

TUD5 Peugeot 106 Engine

[0042] The volumetric composition of the current WEE is 70% diesel oil and 30% water. Cavitation water vapor bubbles in the emulsion represent approximately 1.5% by volume, having an average diameter of 0.1-0.17 microns, with a diameter of water droplets ranging from 0.7-0.95 microns. Storage time before phase separation is 28 days, at a temperature of 30 degrees C. The following table summarizes and contrasts performance of conventional diesel fuel versus the WEE of an embodiment of the current invention.

<table>
<thead>
<tr>
<th>Toxic exhausts</th>
<th>Diesel fuel</th>
<th>WFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>23.7 mg/s</td>
<td>10.9 mg/s</td>
</tr>
<tr>
<td>CO</td>
<td>1400 mg/m³</td>
<td>781 mg/m³</td>
</tr>
<tr>
<td>exhaust opacity</td>
<td>11 mg/s</td>
<td>1.98 mg/s</td>
</tr>
</tbody>
</table>

[0043] A controlled run on a city route was performed. The quantity of fuel consumed in the car was 100 liters. The following are derived transit times for the controlled run, using conventional diesel fuel and the present WFE.

<table>
<thead>
<tr>
<th>Transit time of the car</th>
<th>diesel fuel</th>
<th>WFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>84 min</td>
<td></td>
<td>99 min</td>
</tr>
</tbody>
</table>

Example 3

MAN 58/6015 Ship Engine

[0044] The volumetric composition of the current WEE is 85% heavy oil+15% water. Cavitation water vapor bubbles in the emulsion represent approximately 0.9% volume, having an average diameter of 0.08-0.095 microns, with a diameter of water droplets ranging from 0.81-1 microns. Storage time before phase separation is 30 days, at a temperature of 30° C. The table which follows summarizes and contrasts performance of conventional heavy oil fuel versus the present WFE.
Toxic exhausts          Heavy oil          WFE
NOx                    8108 mg/m³        4864 mg/m³
CO                     2040 mg/m³        981 mg/m³
C                       0.84 g/m³        0.16 g/m³

Optimum Running Mode

At average capacity of 4000 HP, fuel consumption is 127.5 l/hour. The consumption rate noted above infers a fuel savings of 12%.

It will be appreciated that the above descriptions are intended only to serve as examples, and that many other embodiments are possible within the scope of the present invention as defined in the appended claims.

What is claimed is:

1. A fuel emulsion having a three-phase composition, based on at least one hydrocarbon and on water, the fuel emulsion comprising:
   a continuous hydrocarbon phase;
   a phase of cavitation water vapor bubbles dispersed within the continuous hydrocarbon phase;
   a phase of water droplets dispersed within the continuous hydrocarbon phase,
   wherein the emulsion is obtainable by vibroacoustic processing.

2. A fuel emulsion according to claim 1, wherein the volumetric proportion of cavitation water vapor bubbles ranges from 0.25% to less than 1.5%.

3. A fuel emulsion according to claim 1, wherein the average diameter of water droplets is less than or substantially equal to 1 micron.

4. A fuel emulsion according to claim 1, wherein the average diameter of cavitation water vapor bubbles is less than or substantially equal to 0.2 microns.

5. A fuel emulsion according to claim 1, wherein the hydrocarbon includes at least one chosen from the list including: diesel oil, heavy oil; furnace oil; biofuel; gasoline; kerosene; and alcohol.

6. A fuel emulsion according to claim 1, wherein the volume ratio of hydrocarbon to water ranges from substantially 90:10 to substantially 70:30.

7. A method of preparing a fuel emulsion having a three-phase composition, based on at least one hydrocarbon and on water, involving the steps of:
   a. mixing the at least one hydrocarbon and water; and
   b. processing the mixture of hydrocarbon and water in a vibroacoustic mixer to yield a three-phased emulsion having a continuous phase of the hydrocarbon and respective dispersed phases of water droplets and cavitation water vapor bubbles.

8. A method according to claim 7, wherein the average diameter of the water droplets is less than or approximately equal to 1 micron.

9. A method according to claim 7, wherein the average size of the cavitation water vapor bubbles is less than or approximately equal to 0.2 microns.

10. A method according to claim 7, wherein the cavitation water bubble phase in the emulsion ranges from substantially less than 1.5% to greater than 0.25% by volume.

11. A method according to claim 7, wherein mixing the at least one hydrocarbon and water is performed with a volumetric ratio of hydrocarbon to water ranging from substantially 90:10 to substantially 70:30.

12. A method according to claim 7, wherein the hydrocarbon includes at least one chosen from the list including: diesel oil, heavy oil; furnace oil; biofuel; gasoline; kerosene; and alcohol.

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