

FUEL COMPOSITIONS

Field of the Invention

The present invention relates to a liquid fuel composition, in particular to a liquid fuel composition which provides improved engine power and which has a reduced burn duration in an internal combustion engine. The present invention also relates to methods of improving the power output of an internal combustion engine as well as increasing efficiency and reducing emissions, by fueling the internal combustion engine with the liquid fuel composition described herein below. The present invention also relates to methods of improving the burn duration of a liquid fuel composition.

Background of the Invention

In order to improve engine efficiency, power and acceleration properties of modern spark ignition internal combustion engines, these engines are increasingly being downsized and boosted as well as moving up in compression ratios.

As well as upgrading the engine hardware, it is also possible to improve engine efficiency, reduce emissions, increase power and acceleration of spark ignition engines by making changes to the fuel formulations used to fuel the engines. For example, gasoline fuel compositions containing specially formulated refinery components with high octane and good flame speed/burn duration properties can deliver increases in power and/or acceleration as well as fuel economy. However, it would be desirable to be able to use market available, standard exchange gasoline fuel for upgrading power, acceleration and fuel efficiency performance.

So-called high reactivity polybutene polymers have relatively high proportions (i.e. >30%) of polymer molecules having a terminal vinylidene group. US 6,048,373 discloses a fuel composition comprising a spark ignition fuel, a Mannich detergent and a polybutene having a molecular weight distribution of less than 1.4 for controlling intake valve deposits and minimizing valve sticking in spark ignition internal combustion engines. Preferred polybutenes disclosed therein have a number average molecular weight (M_n) of from about 500 to about 2000, and high reactivity polyisobutylenes (PIBs) are disclosed. Preferred treat rates for the polybutene(s) having a molecular weight distribution of 1.4 or less are stated to fall within the range of about 0.5 to about 50 ptb, preferably in the range of about 1.5 to about 40 ptb. The treat rate of the high reactivity PIB used in Example 2 is 53.2 ptb which is equivalent to about 151 ppm. However, there is no teaching in this document of the use of a low molecular weight polybutene polymer at selected treat rates for providing increased engine power and reduced burn duration.

It has now surprisingly been found that the use of a a low molecular weight polybutene, such as a low molecular weight polyisobutylene (PIB), especially a low molecular weight, high reactivity, polyisobutylene (PIB), in a gasoline fuel composition, at selected additive treat rates, can provide benefits in terms of improved power output (increased P_{max}) and reduced burn duration, even when a standard exchange gasoline fuel is used. A reduction in burn duration leads to a more complete burn per cycle, which improves engine efficiency as well as lowers harmful emissions including particulate matter (PM/PN).

Summary of the Invention

According to the present invention there is provided a fuel composition comprising:

- (a) a gasoline base fuel suitable for use in a spark
5 ignition internal combustion engine; and
(b) a polybutene polymer;

wherein the polybutene polymer has a number average
molecular weight in the range from 200 to 10,000 g/mol,
wherein greater than 30% of the polymer molecules in the
10 polybutene polymer have a terminal vinylidene group and
wherein the polybutene polymer is present at a level from
500ppm to 5000ppm, by weight of the fuel composition.

It has been surprisingly found that the fuel
compositions of the present invention provide improved
15 power output as reflected in increased P_{max} , as well as
reduced burn duration of the fuel. Further the fuel
compositions of the present invention exhibit excellent
acceleration, energy efficiency and fuel economy.

According to another aspect of the present invention
20 there is provided a method of improving the power output
of an internal combustion engine, said method comprising
fuelling the internal combustion engine with a liquid
fuel composition comprising:

- (a) a gasoline base fuel suitable for use in a spark
25 ignition internal combustion engine; and
(b) a polybutene polymer;

wherein the polybutene polymer has a number average
molecular weight in the range from 200 to 10,000 g/mol,
and wherein the polybutene polymer is present at a level
30 from 500ppm to 5000ppm, by weight of the fuel
composition, preferably wherein the polybutene is a high
reactivity polybutene wherein greater than 30% of the
polymer molecules in the polybutene polymer have a

terminal vinylidene group.

According to another aspect of the present invention there is provided a method of increasing the $P_{\max}$ of an internal combustion engine, said method comprising
5 fuelling the internal combustion engine with a liquid fuel composition comprising:

(a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

(b) a polybutene polymer;

10 wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high
15 reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.

According to yet another aspect of the present invention there is provided a method of reducing the burn
20 duration of a liquid fuel composition in an internal combustion engine, wherein the method comprises blending a polybutene polymer with a gasoline base fuel to produce a gasoline fuel composition, wherein the polybutene polymer is blended with the gasoline base fuel at a level
25 from 500ppm to 5000ppm, by weight of the gasoline fuel composition and wherein the polybutene has a molecular weight in the range from 200 to 10,000 g/mol and combusting the fuel composition in the spark ignition internal combustion, preferably wherein the polybutylene
30 is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.

According to yet another aspect of the present

invention there is provided the use of a liquid fuel composition for improving power output of an internal combustion engine, wherein the liquid fuel composition comprises:

5 (a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

(b) a polybutene polymer;

wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.

15 According to yet another aspect of the present invention there is provided the use of a liquid fuel composition for increasing the P_{max} of an internal combustion engine, wherein the liquid fuel composition comprises:

20 (a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

(b) a polybutene polymer;

wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.

30 According to yet another aspect of the present invention there is provided the use of a polybutene

polymer in a liquid fuel composition for reducing burn duration, wherein the liquid fuel composition comprises:

(a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

5 (b) a polybutene polymer;

wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.

Brief Description of the Drawings

15 Figure 1 is a graphical representation of the average $P_{\max}$ data shown in Table 3 measured at engine conditions of 1300rpm and 11.5 bar.

Figure 2 is a graphical representation of the average $P_{\max}$ data shown in Table 3 measured at engine
20 conditions of 3300rpm and 12.4 bar.

Figure 3 is a graphical representation of the $P_{\max}$ data in Table 5 and shows the average $P_{\max}$ generated by the combustion for the base fuel and the test fuel on each day (Examples 2-7) at 1300 rpm and 11.5 bar (IGN 2
25 degree BTDC).

Figure 4 is a graphical representation of the $P_{\max}$ data in Table 5 and shows the average % difference in $P_{\max}$ versus the base fuel control run that day for each of Examples 2-7 (with base fuel results in Table 5
30 normalized to zero).

Figure 5 is a graphical representation of the burn duration data in Table 5 and shows the average % difference in burn duration versus the base fuel control

run that day for each of Examples 7-11 (with base fuel results in Table 5 normalized to zero).

Figure 6 is a graphical representation of the average $P_{\max}$ data shown in Table 7 measured at engine conditions of 1300rpm and 11.5 bar.

Figure 7 is a graphical representation of the average burn duration data shown in Table 7 (at 1300 rpm and 11.5 bar).

Detailed Description of the Invention

The term "power output" as used herein refers to the amount of resistance power required to maintain a fixed speed at wide open throttle conditions in Chassis Dynamometer testing.

The term ' $P_{\max}$ ' as used herein refers to the direct measurement of the force generated by decomposition of the fuel.

According to the present invention, there is provided a method of improving the power output of an internal combustion engine. Also, according to the present invention, there is a method of improving the $P_{\max}$ of an internal combustion engine. In the context of these aspects of the present invention, the term "improving" embraces any degree of improvement. The improvement may for instance be 0.05% or more, preferably 0.1% or more, more preferably 0.2% or more, even more preferably 0.5% or more, especially 1% or more, more especially 2% or more, even more especially 5% or more, of the power output or $P_{\max}$ provided by an analogous fuel formulation, prior to adding a low molecular weight, preferably high reactivity, polybutene to it in accordance with the present invention. The improvement in power output or $P_{\max}$ may even be as high as 10% of the power output or $P_{\max}$ provided by an analogous fuel

formulation, prior to adding a low molecular weight, preferably high reactivity, polybutene to it in accordance with the present invention.

5 The low molecular weight, preferably high reactivity, polybutene may also be used to improve the acceleration of an internal combustion engine. The term "acceleration" as used herein refers to the amount of time required for the engine to increase in speed between two fixed speed conditions in a given gear. In the
10 context of this aspect of the invention, the term "improving" embraces any degree of improvement, and may be improved by the same percentages as the power and or $P_{\max}$ is increased above.

15 In accordance with the present invention, the power output and acceleration provided by a fuel composition may be determined in any manner known to a person skilled in the art for instance as taught in SAE Paper 2005-01-0239 and SAE Paper 2005-01-0244.

20 The term 'burn duration' as used herein means the time required (in engine crank angle degrees) for combustion to progress from 10% to 90% (referred to as AI 10-90 in the Examples below). The term AI 50-90 is also used in relation to burn duration and means the time required (in engine crank angle degrees) for combustion
25 to progress from 50% to 90%. Investigation of combustion can be carried out by monitoring in-cylinder pressure data. The pressure data can be collected using a piezoelectric pressure transducer from which the mass fraction burn (MFB), or burn duration can be calculated.
30 Further information on how the MFB can be calculated can be found in SAE Paper 2014-01-1336 published 04/01/2014 by Ftwi Yohaness Hagos and Abd Rashid Abd Aziz entitled 'Mass Fraction Burn Investigation of Lean Burn Low BTU

Gasification Gas in Direct-injection Spark-ignition Engine'.

According to the present invention, there is provided a method of reducing the burn duration of a gasoline fuel composition wherein the method comprises adding a polybutene polymer to the gasoline fuel composition, wherein the polybutene polymer is added at a level from 500ppm to 5000ppm by weight of the gasoline fuel composition and wherein the polybutene has a number average molecular weight in the range from 200 to 10,000 g/mol.

In accordance with the present invention, the burn duration of a fuel composition may be determined in any known manner, for instance using the test method disclosed in the Examples section hereinbelow.

In the context of this aspect of the invention, the term "reducing the burn duration" embraces any degree of reduction. The reduction may for instance be 0.05% or more, preferably 0.1% or more, more preferably 0.2% or more, even more preferably 0.5% or more, especially 1% or more, more especially 2% or more and even more especially 4% or more, or 5% or more reduction of the burn duration provided by an analogous fuel formulation, prior to adding a low molecular weight, preferably high reactivity, polybutene to it in accordance with the present invention. The reduction in burn duration may even be as high as a 10% reduction of the burn duration provided by an analogous fuel formulation, prior to adding a low molecular weight, preferably high reactivity, polybutene to it in accordance with the present invention.

The term "flame speed" or 'laminar flame speed' (LFS) refers to laminar burning velocity. LFS is a

fundamental measure of flame propagation rate without complication of mixing dynamics. However, in an engine, mixing dynamics play a role, so the measured flame speed is referred to as 'burn rate' and 'burn duration'. The
5 terms 'burn rate' and 'burn duration' are also used herein interchangeably with 'flame speed'. Laminar Burning Velocity (LBV) is a fundamental property of a chemical component. It is defined as the rate (normal to the flame front, under laminar flow conditions) at which
10 unburnt gas propagates to the flame front and reacts to form products.

The flame speed of a fuel composition may be determined in any known manner, for instance measurement of LFS can be performed using any one of the following
15 three methods:

1. Stagnation flame method (up to 5-7 atm)
2. Spherically expanding method, either constant pressure or constant volume (up to 60-80 atm)
3. The heat flux method (up to 5 atm or so).

20 All three of these methods are described in the review publication: Egolfopoulos, F.N., Hansen, N., Ju, Y., Kohse-Höinghaus, K., Law, C.K., and Qi, F. "Advances and challenges in laminar flame experiments and implications for combustion chemistry", *Progress in Energy and Combustion Science* 43 (2014) 36-67,
25 <https://doi.org/10.1016/j.pecs.2014.04.004>.

The following method for measuring flame speed in a constant volume combustion chamber (spherical bomb), ref Gillespie, L.L., M.; Sheppard, C.G.; Wooley, R, *Aspects of laminar and turbulent burning velocity relevant to spark ignition engines*, *Journal of the Society of Automotive Engineers*, 2000 (2000-01-0192).

The following method for measuring flame speed uses

a net pressure method: Mittal, M., Zhu, G. and Schock H.,
'Fast mass-fraction-burned calculation using the net
pressure method for real-time applications', Proc. Instn
Mech Engrs, Part D: J. Automobile Engineering 223 (3)
5 (2009): 389-394.

The liquid fuel composition of the present invention
comprises a base fuel suitable for use in an internal
combustion engine and a low molecular weight, preferably
high reactivity, polybutene. Typically, the base fuel
10 suitable for use in an internal combustion engine is a
gasoline or a diesel fuel, and therefore the liquid fuel
composition of the present invention is typically a
gasoline composition or a diesel fuel composition.
Preferably, the base fuel is a gasoline base fuel.

15 The polybutene for use herein is preferably a high
reactivity polybutene. A high reactivity polybutene is a
polybutene having a relatively high proportion, i.e.
greater than 30%, of polymer molecules having a terminal
vinylidene group. The term 'polybutene' as used herein
20 includes polymers made from pure or substantially pure 1-
butene or isobutene, and polymers made from mixtures of
two or all three of 1-butene, 2-butene and isobutene, as
well as including polymers containing minor amounts,
preferably less than 10% by weight, more preferably less
25 than 5% by weight, of C2, C3, and C5 and higher olefins
as well as diolefins. In a preferred embodiment, the
polybutene is a polyisobutene (also referred to as
'polyisobutylene') preferably wherein at least 90% by
weight, more preferably at least 95% by weight, of the
30 polymer is derived from isobutene.

In a particularly preferred embodiment, the
polybutene is a high reactivity polyisobutylene.

In one embodiment, the high reactivity polybutene

has greater than 40% of polymer molecules having a terminal vinylidene group.

In another embodiment, the high reactivity polybutene polymer has greater than 50% of polymer molecules having a terminal vinylidene group.

In a preferred embodiment, the high reactivity polybutene polymer has greater than 70% of polymer molecules having a terminal vinylidene group.

In another preferred embodiment, the high reactivity polybutene has more than 85% of its double bonds located in the terminal position of the molecule.

The high reactivity polybutene polymer for use herein preferably has a molecular mass distribution of 1.5 or greater, preferably 1.6 or greater, more preferably 1.7 or greater, even more preferably 1.8 or greater.

The polybutene polymer is present at a level of from 500ppm to 5000ppm, preferably from 1000ppm to 5000ppm, more preferably from 2500 to 5000 ppm, by weight of the fuel composition. Examples of preferred levels of polybutene include 2500ppm and 5000ppm, by weight of the fuel composition.

One or more polybutene polymer can be used in the fuel compositions herein. When more than one polybutene polymer is used herein, the total level of polybutene polymer is the same as the ranges given in the previous paragraph.

The polybutene polymer for use herein is a low molecular weight polybutene polymer. As used herein the term 'low molecular weight polybutene' means a polybutene polymer having a number average molecular weight (M_n) in the range from 200 to 10,000 g/mol, preferably from 500 to 5000 g/mol, more preferably from 1000 to 5000 g/mol.

In one embodiment of the invention, the polybutenes, preferably high reactivity polybutenes, for use herein have a number average molecular weight (M_n) from 1000 to 2300 g.mol. In another embodiment of the invention, the polybutenes for use herein have a number average molecular weight (M_n) from 2300 to 5000 g/mol. The number average molecular weight of the polybutene polymer can be determined using Gel Permeation Chromatography.

The high reactivity polybutenes for use herein may be bioderived or non-bioderived. In one embodiment of the invention, the polybutene is a low molecular weight, high reactivity polyisobutylene which is derived from 100% renewable feedstock.

The high reactivity polybutenes for use herein preferably contain less than 1 mg/kg of chlorine.

In one embodiment, the high reactivity polybutene polymer for use herein has a kinematic viscosity at 100°C of 190 mm²/s or greater, preferably in the range of 190 mm²/s to 1500 mm²/s, more preferably in the range from 430 to 1500 mm²/s.

A preferred high reactivity polybutene for use herein has an alpha olefin content of greater than 85%.

Suitable high reactivity polybutenes for use herein include those commercially available from BASF under the tradename Glissopal (RTM) such as Glissopal (RTM) 1000, Glissopal (RTM) 1300 and Glissopal (RTM) 2300.

Glissopal (RTM) 1000 has a number average molecular weight (M_n) of 1000 g/mol, a molecular mass distribution (M_w/M_n) of 1.6, an alpha olefin content of greater than 85%, a kinematic viscosity at 100°C of 190 mm²/s and a chlorine content of less than 1 mg/kg.

Glissopal (RTM) 1300 has a number average molecular weight (M_n) of 1300 g/mol, a molecular mass distribution

(M_w/M_n) of 1.7, an alpha olefin content of greater than 85%, a kinematic viscosity at 100°C of 190 mm²/s and a chlorine content of less than 1 mg/kg.

5 Glissopal (RTM) 2300 has a number average molecular weight (M_n) of 2300, a molecular mass distribution (M_w/M_n) of 1.6, an alpha olefin content of greater than 85%, a kinematic viscosity at 100°C of 190 mm²/s and a chlorine content of less than 1 mg/kg.

10 Also suitable for use herein are Glissopal (RTM) 1000, 1300 and 2300 BMBcert (TM) which are low molecular weight, highly reactive polyisobutenes derived from 100% renewable feedstock, commercially available from BASF.

15 The polybutene polymer may be blended together with any other additives e.g. additive performance package(s) to produce an additive blend. The additive blend is then added to a base fuel to produce a liquid fuel composition.

20 The amount of performance package(s) in the additive blend is preferably in the range of from 0.1 to 99.8 wt%, more preferably in the range of from 5 to 50 wt%, by weight of the additive blend.

25 Preferably, the amount of the performance package present in the liquid fuel composition of the present invention is in the range of 15 ppmw (parts per million by weight) to 10 %wt, based on the overall weight of the liquid fuel composition. More preferably, the amount of the performance package present in the liquid fuel composition of the present invention additionally accords with one or more of the parameters (i) to (xv) listed below:

- 30 (i) at least 100 ppmw
(ii) at least 200 ppmw
(iii) at least 300 ppmw

- (iv) at least 400 ppmw
- (v) at least 500 ppmw
- (vi) at least 600 ppmw
- (vii) at least 700 ppmw
- 5 (viii) at least 800 ppmw
- (ix) at least 900 ppmw
- (x) at least 1000 ppmw
- (xi) at least 2500ppmw
- (xii) at most 5000ppmw
- 10 (xiii) at most 10000 ppmw
- (xiv) at most 2 %wt.
- (xv) at most 5 %wt.

In the liquid fuel compositions of the present invention, if the base fuel used is a gasoline, then the gasoline may be any gasoline suitable for use in an internal combustion engine of the spark-ignition (petrol) type known in the art, including automotive engines as well as in other types of engine such as, for example, off road and aviation engines. The gasoline used as the base fuel in the liquid fuel composition of the present invention may conveniently also be referred to as 'base gasoline'. The gasoline may also comprise various levels of bio-components and bio-streams at any level while maintaining appropriate analytical specifications. The bio-components may come from any biomass conversion processes including variations of uncatalyzed and catalyzed biomass pyrolyses, hydro-thermal liquefaction, non-thermal biomass conversions such as microbe catalyzed biochemical processes, etc. Any biomass suitable as feedstock to these processes is ideal.

Gasolines typically comprise mixtures of hydrocarbons boiling in the range from 25 to 230°C (EN-ISO 3405), the optimal ranges and distillation curves

typically varying according to climate and season of the year. The hydrocarbons in a gasoline may be derived by any means known in the art, conveniently the hydrocarbons may be derived in any known manner from straight-run
5 gasoline, synthetically-produced aromatic hydrocarbon mixtures, thermally or catalytically cracked hydrocarbons, hydro-cracked petroleum fractions, catalytically reformed hydrocarbons or mixtures of these.

The specific distillation curve, hydrocarbon
10 composition, research octane number (RON) and motor octane number (MON) of the gasoline are not critical.

Conveniently, the research octane number (RON) of the gasoline may be at least 80, for instance in the range of from 80 to 110, preferably the RON of the
15 gasoline will be at least 90, for instance in the range of from 90 to 110, more preferably the RON of the gasoline will be at least 91, for instance in the range of from 91 to 105, even more preferably the RON of the gasoline will be at least 92, for instance in the range
20 of from 92 to 103, even more preferably the RON of the gasoline will be at least 93, for instance in the range of from 93 to 102, and most preferably the RON of the gasoline will be at least 94, for instance in the range of from 94 to 100 (EN 25164); the motor octane number
25 (MON) of the gasoline may conveniently be at least 70, for instance in the range of from 70 to 110, preferably the MON of the gasoline will be at least 75, for instance in the range of from 75 to 105, more preferably the MON of the gasoline will be at least 80, for instance in the
30 range of from 80 to 100, most preferably the MON of the gasoline will be at least 82, for instance in the range of from 82 to 95 (EN 25163).

Typically, gasolines comprise components selected

from one or more of the following groups; saturated hydrocarbons, olefinic hydrocarbons, aromatic hydrocarbons, and oxygenated hydrocarbons. Conveniently, the gasoline may comprise a mixture of saturated hydrocarbons, olefinic hydrocarbons, aromatic hydrocarbons, and, optionally, oxygenated hydrocarbons.

Typically, the olefinic hydrocarbon content of the gasoline is in the range of from 0 to 40 percent by volume based on the gasoline (ASTM D1319); preferably, the olefinic hydrocarbon content of the gasoline is in the range of from 0 to 30 percent by volume based on the gasoline, more preferably, the olefinic hydrocarbon content of the gasoline is in the range of from 0 to 20 percent by volume based on the gasoline.

Typically, the aromatic hydrocarbon content of the gasoline is in the range of from 0 to 70 percent by volume based on the gasoline (ASTM D1319), for instance the aromatic hydrocarbon content of the gasoline is in the range of from 10 to 60 percent by volume based on the gasoline; preferably, the aromatic hydrocarbon content of the gasoline is in the range of from 0 to 50 percent by volume based on the gasoline, for instance the aromatic hydrocarbon content of the gasoline is in the range of from 10 to 50 percent by volume based on the gasoline.

In one embodiment herein the gasoline base fuel comprises less than 10 vol% of aromatics, based on the total base fuel. In another embodiment herein, the gasoline base fuel comprises less than 2 vol% of aromatics having 9 carbon atoms or greater, based on the total base fuel.

The benzene content of the gasoline is at most 10 percent by volume, more preferably at most 5 percent by volume, especially at most 1 percent by volume based on the gasoline.

The gasoline preferably has a low or ultra low sulphur content, for instance at most 1000 ppmw (parts per million by weight), preferably no more than 500 ppmw, more preferably no more than 100, even more preferably no more than 50 and most preferably no more than even 10 ppmw.

The gasoline also preferably has a low total lead content, such as at most 0.005 g/l, most preferably being lead free - having no lead compounds added thereto (i.e. unleaded).

When the gasoline comprises oxygenated hydrocarbons, at least a portion of non-oxygenated hydrocarbons will be substituted for oxygenated hydrocarbons (match-blending) or simply added to the fully formulated gasoline (splash-blending). The oxygenate content of the gasoline may be up to 85 percent by weight (EN 1601) (e.g. ethanol per se) based on the gasoline. For example, the oxygenate content of the gasoline may be up to 35 percent by weight, preferably up to 25 percent by weight, more preferably up to 10 percent by weight. Conveniently, the oxygenate concentration will have a minimum concentration selected from any one of 0, 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2 percent by weight, and a maximum concentration selected from any one of 12, 8, 7.2, 5, 4.5, 4.0, 3.5, 3.0, and 2.7 percent by weight.

Examples of oxygenated hydrocarbons that may be incorporated into the gasoline include alcohols, ethers, esters, ketones, aldehydes, carboxylic acids and their derivatives, and oxygen containing heterocyclic compounds. Preferably, the oxygenated hydrocarbons that may be incorporated into the gasoline are selected from alcohols (such as methanol, ethanol, propanol, 2-propanol, butanol, tert-butanol, iso-butanol and 2-

butanol), ethers (preferably ethers containing 5 or more carbon atoms per molecule, e.g., methyl tert-butyl ether and ethyl tert-butyl ether) and esters (preferably esters containing 5 or more carbon atoms per molecule); a particularly preferred oxygenated hydrocarbon is ethanol.

When oxygenated hydrocarbons are present in the gasoline, the amount of oxygenated hydrocarbons in the gasoline may vary over a wide range. For example, gasolines comprising a major proportion of oxygenated hydrocarbons are currently commercially available in countries such as Brazil and U.S.A., e.g. ethanol per se and E85, as well as gasolines comprising a minor proportion of oxygenated hydrocarbons, e.g. E10 and E5. Therefore, the gasoline may contain up to 100 percent by volume oxygenated hydrocarbons. E100 fuels as used in Brazil are also included herein. Preferably, the amount of oxygenated hydrocarbons present in the gasoline is selected from one of the following amounts: up to 85 percent by volume; up to 70 percent by volume; up to 65 percent by volume; up to 30 percent by volume; up to 20 percent by volume; up to 15 percent by volume; and, up to 10 percent by volume, depending upon the desired final formulation of the gasoline. Conveniently, the gasoline may contain at least 0.5, 1.0 or 2.0 percent by volume oxygenated hydrocarbons.

Examples of suitable gasolines include gasolines which have an olefinic hydrocarbon content of from 0 to 20 percent by volume (ASTM D1319), an oxygen content of from 0 to 5 percent by weight (EN 1601), an aromatic hydrocarbon content of from 0 to 50 percent by volume (ASTM D1319) and a benzene content of at most 1 percent by volume.

Also suitable for use herein are gasoline blending

components which can be derived from sources other than crude oil, such as low carbon gasoline fuels from either biomass or CO₂, and blends thereof which each other or with fossil-derived gasoline streams and components.

5 Suitable examples of such fuels include:

1) Biomass derived:

a. Straight run bio-naphthas from hydrodeoxygenation of biomass, and

10 b. cracked and/or isomerized products of syn-wax (biomass gasification to syngas (CO/H₂) then to syn-wax by the Fischer-Tropsch (FT) process, which is then hydrocracked/hydroisomerized to yield a slate of products including cuts in the gasoline distillation range.

2) CO₂ derived:

15 a. CO₂ + H₂ syngas (CO/H₂) by modified water/gas shift reaction, then to syn-wax by the FT process), which is then hydrocracked/hydroisomerized to yield a slate of products including cuts in the gasoline distillation range.

20 3) Methanol derived:

a. Biomass gasification to syngas (CO/H₂), then to Methanol and then gasoline by the MTG process (MTG is 'methanol-to-gasoline' process). To reduce the carbon intensity of the fuel further, the H₂ used in all
25 processes would be renewable (green) H₂ from electrolysis of water using renewable electricity such as from wind and solar.

Particularly suitable for use herein are gasoline blending components which can be derived from a
30 biological source. Examples of such gasoline blending components can be found in WO2009/077606, WO2010/028206, WO2010/000761, European patent application nos. 09160983.4, 09176879.6, 09180904.6, and US patent

application serial no. 61/312307.

Whilst not critical to the present invention, the base gasoline or the gasoline composition of the present invention may conveniently include one or more optional
5 fuel additives, in addition to the low molecular weight, preferably high reactivity, polybutene. The concentration and nature of the optional fuel additive(s) that may be included in the base gasoline or the gasoline composition of the present invention is not critical.

10 Non-limiting examples of suitable types of fuel additives that can be included in the base gasoline or the gasoline composition of the present invention include anti-oxidants, corrosion inhibitors, detergents, dehazers, antiknock additives, metal deactivators, valve-seat
15 recession protectant compounds, dyes, solvents, carrier fluids, diluents and markers. Examples of suitable such additives are described generally in US Patent No. 5,855,629.

Conveniently, the fuel additives can be blended with
20 one or more solvents to form an additive concentrate, the additive concentrate can then be admixed with the base gasoline or the gasoline composition of the present invention.

The (active matter) concentration of any optional
25 additives present in the base gasoline or the gasoline composition of the present invention is preferably up to 1 percent by weight, more preferably in the range from 5 to 2000 ppmw, advantageously in the range of from 300 to 1500 ppmw, such as from 300 to 1000 ppmw.

30 Further customary additives for use in gasolines are corrosion inhibitors, for example based on ammonium salts of organic carboxylic acids, said salts tending to form films, or of heterocyclic aromatics for nonferrous metal

corrosion protection; dehazers; anti-knock additives;
metal deactivators; solvents; carrier fluids; diluents;
antioxidants or stabilizers, for example based on amines
such as phenyldiamines, e.g. p-phenylenediamine, N,N'-di-
5 sec-butyl-p-phenyldiamine, dicyclohexylamine or
derivatives thereof or of phenols such as 2,4-di-tert-
butylphenol or 3,5-di-tert-butyl-4-hydroxy-
phenylpropionic acid; anti-static agents; metallocenes
such as ferrocene; methylcyclopentadienylmanganese
10 tricarbonyl; lubricity additives, such as certain fatty
acids, alkenylsuccinic esters, bis(hydroxyalkyl) fatty
amines, hydroxyacetamides or castor oil; and also dyes
(markers). Suitable such additives are disclosed in US
Patent No. 5,855,629. Amines may also be added, if
15 appropriate, for example as described in WO 03/076554.
Optionally anti valve seat recession additives may be
used such as sodium or potassium salts of polymeric
organic acids.

The gasoline compositions herein can also comprise a
20 detergent additive. Suitable detergent additives include
those disclosed in WO2009/50287, incorporated herein by
reference.

Preferred detergent additives for use in the
gasoline composition herein typically have at least one
25 hydrophobic hydrocarbon radical having a number-average
molecular weight (Mn) of from 85 to 20 000 and at least
one polar moiety selected from:

(A1) mono- or polyamino groups having up to 6
nitrogen atoms, of which at least one nitrogen atom has
30 basic properties;

(A6) polyoxy-C₂- to -C₄-alkylene groups which are
terminated by hydroxyl groups, mono- or polyamino groups,
in which at least one nitrogen atom has basic properties,

or by carbamate groups;

(A8) moieties derived from succinic anhydride and having hydroxyl and/or amino and/or amido and/or imido groups; and/or

5 (A9) moieties obtained by Mannich reaction of substituted phenols with aldehydes and mono- or polyamines.

The hydrophobic hydrocarbon radical in the above detergent additives, which ensures the adequate
10 solubility in the base fluid, has a number-average molecular weight (Mn) of from 85 to 20 000, especially from 113 to 10 000, in particular from 300 to 5000. Typical hydrophobic hydrocarbon radicals, especially in conjunction with the polar moieties (A1), (A8) and (A9),
15 include polyalkenes (polyolefins), such as the polypropenyl, polybutenyl and polyisobutenyl radicals each having Mn of from 300 to 5000, preferably from 500 to 2500, more preferably from 700 to 2300, and especially from 700 to 1000.

20 Non-limiting examples of the above groups of detergent additives include the following:

Additives comprising mono- or polyamino groups (A1) are preferably polyalkenemono- or polyalkenepolyamines based on polypropene or conventional (i.e. having
25 predominantly internal double bonds) polybutene or polyisobutene having Mn of from 300 to 5000. When polybutene or polyisobutene having predominantly internal double bonds (usually in the beta and gamma position) are used as starting materials in the preparation of the
30 additives, a possible preparative route is by chlorination and subsequent amination or by oxidation of the double bond with air or ozone to give the carbonyl or carboxyl compound and subsequent amination under

reductive (hydrogenating) conditions. The amines used here for the amination may be, for example, ammonia, monoamines or polyamines, such as dimethylaminopropylamine, ethylenediamine, diethylene-
5 triamine, triethylenetetramine or tetraethylenepentamine. Corresponding additives based on polypropene are described in particular in WO-A-94/24231.

Further preferred additives comprising monoamino groups (A1) are the hydrogenation products of the
10 reaction products of polyisobutenes having an average degree of polymerization of from 5 to 100, with nitrogen oxides or mixtures of nitrogen oxides and oxygen, as described in particular in WO-A-97/03946.

Further preferred additives comprising monoamino
15 groups (A1) are the compounds obtainable from polyisobutene epoxides by reaction with amines and subsequent dehydration and reduction of the amino alcohols, as described in particular in DE-A-196 20 262.

Additives comprising polyoxy-C₂-C₄-alkylene moieties
20 (A6) are preferably polyethers or polyetheramines which are obtainable by reaction of C₂- to C₆₀-alkanols, C₆- to C₃₀-alkanediols, mono- or di-C₂-C₃₀-alkylamines, C₁-C₃₀-alkylcyclohexanols or C₁-C₃₀-alkylphenols with from 1 to 30 mol of ethylene oxide and/or propylene oxide and/or
25 butylene oxide per hydroxyl group or amino group and, in the case of the polyether-amines, by subsequent reductive amination with ammonia, monoamines or polyamines. Such products are described in particular in EP-A-310 875, EP-A-356 725, EP-A-700 985 and US-A-4 877 416. In the case
30 of polyethers, such products also have carrier oil properties. Typical examples of these are tridecanol butoxylates, isotridecanol butoxylates, isononylphenol butoxylates and polyisobutenol butoxylates and

propoxylates and also the corresponding reaction products with ammonia.

Additives comprising moieties derived from succinic anhydride and having hydroxyl and/or amino and/or amido and/or imido groups (A8) are preferably corresponding derivatives of polyisobutenylsuccinic anhydride which are obtainable by reacting conventional or highly reactive polyisobutene having Mn of from 300 to 5000 with maleic anhydride by a thermal route or via the chlorinated polyisobutene. Of particular interest are derivatives with aliphatic polyamines such as ethylenediamine, diethylenetriamine, triethylenetetramine or tetraethylenepentamine. Such additives are described in particular in US-A-4 849 572.

Additives comprising moieties obtained by Mannich reaction of substituted phenols with aldehydes and mono- or polyamines (A9) are preferably reaction products of polyisobutene-substituted phenols with formaldehyde and mono- or polyamines such as ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine or dimethylaminopropylamine. The polyisobutenyl-substituted phenols may stem from conventional or highly reactive polyisobutene having Mn of from 300 to 5000. Such "polyisobutene-Mannich bases" are described in particular in EP-A-831 141.

Preferably, the detergent additive used in the gasoline compositions of the present invention contains at least one nitrogen-containing detergent, more preferably at least one nitrogen-containing detergent containing a hydrophobic hydrocarbon radical having a number average molecular weight in the range of from 300 to 5000. Preferably, the nitrogen-containing detergent is selected from a group comprising polyalkene

monoamines, polyetheramines, polyalkene Mannich amines and polyalkene succinimides. Conveniently, the nitrogen-containing detergent may be a polyalkene monoamine.

5 In the above, amounts (concentrations, % vol, ppmw, % wt) of components are of active matter, i.e. exclusive of volatile solvents/diluent materials.

10 The liquid fuel composition of the present invention can be produced by admixing the essential low molecular weight, preferably high reactivity, polybutene polymer with a gasoline base fuel suitable for use in an internal combustion engine. Since the base fuel to which the essential fuel additive is admixed is a gasoline, then the liquid fuel composition produced is a gasoline composition.

15 It has surprisingly been found that the use of a combination of a low molecular weight, preferably high reactivity, polybutene having a number average molecular weight of from 500 to 10,000 g/mol, and present in an amount of 500 to 5000 ppm, by weight of the fuel
20 composition provides benefits in terms of improved power and increased $P_{\max}$ of an internal combustion engine being fuelled by the liquid fuel composition containing said polybutene, relative to the internal combustion engine being fuelled by the liquid base fuel. In a preferred
25 embodiment herein, an improvement in power can be observed at low load and low speed conditions (such as at 1300 rpm and 11.5 bar) as well as at high load and high speed conditions (such as at 3300 rpm and 12.4 bar). It has been found that a high reactivity polyisobutylene
30 polymer having a molecular weight of 2300 or greater is particularly beneficial at providing an increase in power output at low speed/low load conditions.

It has also surprisingly been found that the the use

of a combination of a low molecular weight, preferably high reactivity, polybutene having a number average molecular weight of from 500 to 10,000 g/mol, and present in an amount of 500 ppm to 5000 ppm, by weight of the fuel composition provides benefits in terms of reduced burn duration of the liquid fuel composition containing said polybutene, relative to the internal combustion engine being fuelled by the liquid base fuel

The present invention will be further understood from the following examples. Unless otherwise stated, all amounts and concentrations disclosed in the examples are based on weight of the fully formulated fuel composition.

Examples

Example 1

A set of experiments was conducted to test a high reactivity polyisobutylene (PIB) for combustion enhancing properties using the gasoline single cylinder engine (GSCE). The base fuel was a RON 96 E10 base gasoline fuel containing 28% aromatics meeting North American premium specification ASTM D4814 containing no performance additive. A high-reactivity polyisobutylene (PIB) having an average number molecular weight (M_n) of 1000 g/mol, commercially available from BASF under the tradename Glissopal (RTM) 1000, was added into the base fuel at a treat rate of 5000 ppm.

Test Conditions

The engine used for these experiments was a Gasoline single cylinder engine. This engine was manufactured by AVL and based on the EA888 2.0L Audi TFSI/VW TSI (Euro 6). The single cylinder bench engine details are shown in Table 1 below.

Table 1

Parameter:	Details:
Manufacturer	AVL
Displaced Volume	454 cm ³
Cylinders	1
Stroke	86 mm
Bore	82 mm
Compression ratio	Variable 8-12, (10:1 chosen)
Number of valves	2 inlet; 2 outlet
Maximum engine speed	5000 rpm (3300 rpm chosen)
Aspiration	Slightly Boosted (max 2.5 bar absolute)
Injection	PFI (solenoid injector)
Other	IMEP up to 25 bar, Max. peak pressure 130 bar continuous

The engine test conditions are detailed below in Table 2.

Table 2

Engine test conditions	Speed [RPM]	IMEP [Bar]	Intake pressure [mbara]	Intake temp. [°C]	Exhaust back pressure [mbara]	Fuel pressure [bar]	Fuel temp [°C]
1300HL	1300	11.5	1110	35	1080	3	25
1300ML	1300	8	905	35	1080	3	25
3300HL	3300	12.4	1205	35	1850	3	25

5 The test protocol below was run with base fuel and one test fuel per day:

- Warm up engine and line out on base fuel
- Run baseline spark sweep: 1300 ML, HL, 3000 ML (ML = medium load; HL = high load)
- 10 • Switch to test fuel and flush 30 litre
- Test: spark sweep at three different conditions (1300 rpm, IMEP: 11.5 bar and 8 bar; and 3300 rpm, IMEP: 12.4 bar)
- End.

15 Each test fuel blend was screened twice, once in each of two randomized loops.

The average maximum pressure ($P_{\max}$) generated by the

combustion for the base fuel and for the test fuel (Example 1) is shown in Table 3 below and in Figures 1 and 2.

Table 3

Example	Dose PIB (1000) (ppm)	RON	MON	RON- MON	Average P _{max} , bar (1300 rpm, 11.5 bar)	Average P _{max} , bar (3300 rpm, 12.4 bar)
Base Fuel	0	96.7	85	11.7	52.13	58.90
Example 1	5000ppm	96.4	85	11.4	53.62	59.13

5 Figure 1 shows the average P_{max} generated by the combustion for the base fuel and the test fuel (Example 1) at 1300 rpm and 11.5 bar.

 Figure 2 shows the average P_{max} generated by the combustion for the base fuel and the test fuel (Example 1) at 3300 rpm and 12.4 bar.

Examples 2 to 7

 Another set of experiments was done on some further test fuel blends using the same base fuel as in Example 1 above and using the same test conditions and test protocol as used above in Example 1. The test fuel blends of Examples 2 to 7 each containing a high reactivity PIB are shown in Table 4 below. The molecular weight of the high reactivity PIB used in each fuel is shown in brackets in column 2 of Table 4. Two different HR-PIBs were used, one having a number average molecular weight of 1000 g/mol, commercially available from BASF under the tradename Glissopal (RTM) 1000, and the other having a number average molecular weight of 2300 g/mol, commercially available from BASF under the tradename Glissopal (RTM) 2300. The treat rate, RON, MON and RON-MON of each of the test blends is also shown in Table 4.

Table 4

Example	PIB (MW)	Dose of PIB, ppmw	RON	MON	RON-MON
2	PIB (1000)	5000	96.5	86	10.5
3	PIB (1000)	2500	96.4	86.1	10.3
4	PIB (1000)	1000	96.4	86.2	10.2
5	PIB (2300)	2500	96.4	85.8	10.6
6	PIB (2300)	5000	96.2	85.9	10.3
7	PIB (2300)	1000	96.3	85.8	10.5

The $P_{\max}$ and the burn duration was measured for each of Examples 2 to 7 as well as for the base fuel and the results are set out in Table 5 below. Table 5 also sets out % difference in $P_{\max}$ and burn duration between each test blend and the base fuel control run that day.

$P_{\max}$ and burn duration are well known metrics known to those skilled in the art. The start of combustion is ignition and the end of combustion is the point of maximum pressure, $P_{\max}$. Combustion duration is the time interval between 10%-90% of the combustion. Further information on how burn duration is calculated can be found in Hosseini, Vahid & Checkel, M. (2006), 'Using reformer gas to enhance HCCI combustion of CNG in a CFR Engine', SAE Technical Papers, DOI: 10.4271/2006-01-3247. Burn duration (or combustion duration) can be determined by the pressure curve as shown in Figure 1 of the Hosseini et al paper. Figure 1 of the Hosseini et al paper shows AI 10-90 and how it relates to the maximum net heat release (HRN) and the maximum pressure release ($P_{\max}$). Either temperature or pressure can be used to calculate the combustion metrics. In the present examples, in-cylinder pressure was used to determine the burn duration.

Table 5

Fuel	P _{max}	% difference	Burn duration (AI 10-90)	% difference
Base fuel	53.41		15.38	
Example 2	54.31	1.69%	15.12	-1.74%
Base fuel	53.18		15.37	
Example 3	53.29	0.20%	15.40	0.21%
Base fuel	53.21		15.44	
Example 4	53.05	-0.30%	15.47	0.16%
Base fuel	53.77		15.27	
Example 5	54.29	0.97%	15.04	-1.52%
Base fuel	53.37		15.36	
Example 6	54.78	2.64%	14.74	-3.99%
Base fuel	53.55		15.23	
Example 7	53.48	-0.14%	15.40	1.09%

Figure 3 is a graphical representation of the P_{max} data in Table 5 and shows the average P_{max} generated by the combustion for the base fuel and the test fuel on each day (Examples 2-7) at 1300 rpm and 11.5 bar (IGN 2 degree BTDC).

Figure 4 is a graphical representation of the P_{max} data in Table 5 and shows the average % difference in P_{max} versus the base fuel control run that day for each of Examples 7-11 (with base fuel results in Table 5 normalized to zero).

Figure 5 is a graphical representation of the burn duration data in Table 5 and shows the average % difference in burn duration versus the base fuel control run that day for each of Examples 7-11 (with base fuel results in Table 5 normalized to zero).

Examples 8 and 9

Another set of experiments was done on some further test fuel blends using a different base fuel from the one used in Example 1. The base fuel used in Examples 8 and 9 was a RON 92 E10 base gasoline fuel containing 6.8% aromatics meeting North American main grade specification ASTM D4814 containing no performance additives. Examples

8 and 9 used the same test conditions and test protocol as used above in Example 1. The test fuel blends of Examples 8 and 9 each containing a high reactivity PIB are shown in Table 6 below. The molecular weight of the high reactivity PIB used in each fuel is shown in brackets in column 2 of Table 6. Two different HR-PIBs were used, one having a number average molecular weight of 1000 g/mol, commercially available from BASF under the tradename Glissopal (RTM) 1000, and the other having a number average molecular weight of 2300 g/mol, commercially available from BASF under the tradename Glissopal (RTM) 2300. The treat rate, RON, MON and RON-MON of each of the test blends is also shown in Table 6.

Table 6

Example	PIB (MW)	Dose of PIB, ppmw	RON	MON	RON-MON
Base Fuel	-	-	92.2	86.8	5.4
8	PIB (2300)	5000	92.1	86.7	5.4
9	PIB (1000)	5000	92.0	86.6	5.4

The P_{max} and the burn duration was measured for each of Examples 8 and 9 as well as for the base fuel and the results are set out in Table 7 below. Table 7 also sets out % difference in P_{max} and burn duration between each test blend and the base fuel control run that day.

Table 7

Fuel	Average P_{max} (1300 rpm, 11.5 bar)	% difference	Burn duration (AI 10-90) (1300 rpm, 11.5 bar)	% difference
Base fuel	48.29		15.07	
Example 8	50.30	4.16%	14.18	-6.28%
Base fuel	48.32		14.99	
Example 9	49.51	2.46%	14.69	-2.04%

Figure 6 is a graphical representation of the P_{max}

data in Table 7 and shows the average $P_{\max}$ generated by the combustion for the base fuel and the test fuel on each day (Examples 8-9) at 1300 rpm and 11.5 bar (IGN 1 degree after TDC).

Figure 7 is a graphical representation of the burn duration data in Table 7 and shows the average burn duration versus the base fuel control run that day for each of Examples 8-9 at 1300 rpm, 11.5 bar (IGN 1 degree after TDC).

Discussion

Use of 5000ppmw by weight of a low molecular weight, high reactivity PIB having a molecular weight of 1000 g/mol in a gasoline fuel composition has been shown to provide increased power (increased $P_{\max}$) versus the base fuel at both low speed/low load and high load/high speed conditions in engine tests (Example 1).

Further, use of 2500ppmw and 5000ppmw of a low molecular weight, high reactivity, PIB having a molecular weight of 1000 g/mol in a gasoline fuel composition has been shown to provide increased power (increased $P_{\max}$) at low speed/low load conditions in engine tests (Examples 2-4).

Further, use of 2500ppmw and 5000ppmw of a low molecular weight, high reactivity, PIB having a molecular weight of 2300 g/mol in a gasoline fuel composition has been shown to provide increased power (increased $P_{\max}$) at low speed/low load conditions in engine tests compared with a base fuel (Examples 5-7). The high reactivity PIB with the higher molecular weight ($M_w = 2300$ g/mol) appears to provide a bigger increase in power at low speed/low load conditions compared with the high reactivity PIB with the lower molecular weight ($M_w = 1000$ g/mol).

Further, use of 5000ppmw of a high reactivity PIB

having a molecular weight of 1000 g/mol in a gasoline fuel composition has been shown to provide reduced burn duration compared with the base fuel (Examples 2-4).

5 Further, use of 2500ppmw and 5000ppmw of a high reactivity PIB having a molecular weight of 2300 g/mol in a gasoline fuel composition has been shown to provide reduced burn duration compared with the base fuel (Examples 5-7).

10 Further, use of 5000ppmw of a high reactivity PIB having a molecular weight of 1000 g/mol in a gasoline fuel composition has been shown to provide increased power (increased Pmax) at low speed/low load conditions in engine tests compared with a base fuel (Example 8).

15 Further, use of 5000ppmw of a high reactivity PIB having a molecular weight of 2300 g/mol in a gasoline fuel composition has been shown to provide increased power (increased Pmax) at low speed/low load conditions in engine tests compared with a base fuel (Example 9).

20 Further, use of 5000ppmw of a high reactivity PIB having a molecular weight of 1000 g/mol in a gasoline fuel composition has been shown to provide reduced burn duration compared with the base fuel (Example 8).

25 Further, use of 5000ppmw of a high reactivity PIB having a molecule weight of 2300 g/mol in a gasoline fuel composition has been shown to provide reduced burn duration compared with the base fuel (Example 9).

C L A I M S

1. Fuel composition comprising:
 - (a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and
 - (b) a polybutene polymer;
- 5 wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group and wherein the polybutene polymer is present at a level from
10 500ppm to 5000ppm, by weight of the fuel composition.
2. Fuel composition according to Claim 1 wherein greater than 40% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.
3. Fuel composition according to Claim 1 or 2 wherein
15 greater than 50% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.
4. Fuel composition according to any of Claims 1 to 3 wherein the polybutene polymer has a number average molecular weight in the range from 500 to 5,000 g/mol.
- 20 5. Fuel composition according to any of Claims 1 to 4 wherein the polybutene polymer has a number average molecular weight in the range from 1000 to 2,300 g/mol.
6. Fuel composition according to any of Claims 1 to 5 wherein the polybutene polymer has a number average
25 molecular weight in the range from 2,300 to 5,000 g/mol.
7. Fuel composition according to any of Claims 1 to 6 wherein the polybutene polymer is present at a level from 1000ppm to 5000ppm, by weight of the fuel composition.
- 30 8. Fuel composition according to any of Claims 1 to 7

wherein the polybutene polymer is present at a level from 2500ppm to 5000ppm, by weight of the fuel composition.

9. Fuel composition according to any of Claims 1 to 8 wherein the polybutene polymer is a polyisobutylene polymer.

10. Use of a liquid fuel composition for improving power output of an internal combustion engine, wherein the liquid fuel composition comprises:

(a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

(b) a polybutene polymer;

wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polyisobutylene polymer have a terminal vinylidene group.

11. Use of a liquid fuel composition for improving the Pmax of an internal combustion engine, wherein the liquid fuel composition comprises:

(a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

(b) a polybutene polymer;

wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a

terminal vinylidene group.

12. Use of a polybutene in a liquid fuel composition for reducing the burn duration wherein the a liquid fuel composition comprises:

5 (a) a gasoline base fuel suitable for use in a spark ignition internal combustion engine; and

(b) a polybutene polymer;

wherein the polybutene polymer has a number average molecular weight in the range from 200 to 10,000 g/mol, and wherein the polybutene polymer is present at a level from 500ppm to 5000ppm, by weight of the fuel composition, preferably wherein the polybutene is a high reactivity polybutene wherein greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group.

13. A method of increasing the power output of a spark ignition internal combustion engine wherein the method comprises adding a polybutene to a gasoline base fuel to produce a gasoline fuel composition, wherein the polybutene polymer is added at a level from 500ppm to 5000ppm by weight of the gasoline fuel composition, wherein the polybutene has a number average molecular weight in the range from 200 to 10,000 g/mol and combusting the fuel composition in the spark ignition internal combustion engine.

14. A method of reducing the burn duration of a gasoline fuel composition in a spark ignition internal combustion engine wherein the method comprises adding a polybutene to a gasoline base fuel to produce a gasoline fuel composition, wherein the polybutene polymer is added at a level from 500ppm to 5000ppm by weight of the gasoline fuel composition, wherein the polybutene has a number average molecular weight in the range from 200 to

10,000 g/mol and combusting the fuel composition in the spark ignition internal combustion engine.

15. A method according to Claim 13 or Claim 14 wherein the polybutene has greater than 30% of the polymer molecules in the polybutene polymer have a terminal vinylidene group the polybutene.
- 5