Fuel 153 (2015) 67–69

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Short communication

Flash points and volatility characteristics of gasoline/diesel blends

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HIGHLIGHTS

- Measured flash points and volatility of blends of a diesel and a gasoline.
- Blends with gasoline >50% volume will have flash points similar to gasoline.
- Such blends will be as safe as gasoline for use in vehicles.

ARTICLE INFO

Article history:
Received 4 December 2014
Received in revised form 18 February 2015
Accepted 18 February 2015
Available online 7 March 2015

Keywords:
Flash point
Gasoline
Diesel
Gasoline compression ignition (GCI)

ABSTRACT

Measured flash points of blends of a commercial diesel and a commercial gasoline are presented along with data on volatility characteristics. The flash point falls very rapidly as the concentration of gasoline is increased and reaches −40 °C at a gasoline concentration of 16% by volume. This suggests that blends with gasoline concentrations of greater than 50% by volume, which are of interest in the development of gasoline compression ignition (GCI) engines, should be safe to use in vehicles because they will be very similar to gasoline which has a flash point of −45 °C.

1. Introduction

The outlook for transport fuels has been summarized in [1]. It is expected that energy for transport will continue to be supplied essentially by liquid fuels made from crude oil in the next several decades as it is today. There will be sufficient oil to meet the increasing demand for transport. However, this growth will be heavily skewed toward commercial transport and hence toward middle distillates (diesel and jet fuel) rather than gasoline. Meanwhile the push for higher efficiency in spark ignition engines will require the octane quality of the gasoline pool to be raised. Such trends suggest that there will be a relative abundance of low octane components in the gasoline boiling range even after investments are made in refineries to meet the changing fuel demand structure.

Compression ignition (CI) engines running on low octane (Research Octane Number, RON of 70–85) gasoline, with higher ignition delays compared to current diesel fuels, could be at least as efficient as current diesel engines but cheaper. This concept, known as gasoline compression ignition (GCI), has been summarized in [1–3]. GCI engines could be more efficient (at least as efficient as diesel) than the most advanced SI engines while using, unlike SI engines, low octane fuels such as naphtha which require less processing in the refinery and could be easily available. They could also be less expensive than advanced diesel engines. Even though the GCI concept has been demonstrated in engines, development work is needed for it to be used in practical vehicles. If such vehicles were to be developed, it would open up an important path to mitigate the expected imbalance in demand growth in favor of middle distillates.

However, such new fuel/engine concepts have to first work with existing market fuels. One approach is to use two fuels, with gasoline injected in the port and diesel fuel injected directly into the cylinder [4–6] but this increases the complexity of the engine. Significant progress has been made to develop a single-fuel multi-cylinder GCI engine using US regular gasoline of 92 RON [7]. Fuels of lower RON would make some of the problems for GCI such as low load operation easier to handle. One alternative might be to use mixtures of gasoline and diesel, "dieseline", to reduce the octane number of the market gasoline to better enable GCI technology e.g. [8,9]. Blends with gasoline concentrations of 50% by volume or more (most likely between 80% and 90% by volume gasoline) would be of interest for such applications. Blends with lower concentrations of gasoline are likely to have autoignition

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http://dx.doi.org/10.1016/j.fuel.2015.02.070
0016-2361/

properties too similar to that of diesel [2]. Such an approach could provide the bridge to full GCI deployment using fuels that are less processed in the refinery compared to either gasoline or diesel.

However, this raises the question of whether dieseline is a safe fuel to carry in the fuel tank of a car. Gasoline and diesel are made up of a wide range of hydrocarbons with different volatilities. The space above the liquid surface in a fuel tank is a mixture of air and fuel vapor which, if ignited by an accidental spark, would pose a fire and explosion hazard. With market gasolines which contain components with boiling points between around 30 °C and 200 °C, at normal ambient temperatures, this mixture is too rich to ignite and hence safe. With diesel fuel, which is significantly less volatile, this mixture would be too lean to ignite. However, it is possible that a blend of the two might produce a vapor/air mixture that might be combustible.

The flammability hazard of the fuel is quantified by its flash point which is the lowest temperature at which the fuel can vaporize to form an ignitable mixture in air. It is measured according to a standard method such as the IP 170 (EN ISO 13736). For European diesel fuel, the EN 590 specification requires the flash point to be at least 55 °C. This means that if the temperature is below 55 °C, as it would be in Europe even in summer, the vapor above the liquid in a vehicle fuel tank would be too lean to be flammable and there would not be a fire hazard. The flash point for gasolines is usually very low, around −45 °C [10] and the vapor above the liquid surface is too rich to be flammable. Adding a more volatile liquid like gasoline to diesel fuel can depress the flash point and increase the flammability hazard. There have been several studies on the flash points of pure components as summarized in [11] and correlations relating the flash point to vapor pressure have been developed. There are also studies of flash points of binary and some ternary blends of components [12,13] which propose some predictive methods. However such methods cannot be used to predict the flash points of blends of full boiling range gasoline and diesel and, to the best of our knowledge, no experimental data for such blends has been published. We present such data in this work. The results suggest that blends of dieseline with gasoline concentrations greater than 20% by volume should be safe.

2. Experimental detail

The automatic flash point tester following IP 170 standard can be used to measure the flash point temperature from room temperature to 70 °C but is not cold enough to test the gasoline flash point. Therefore, the flash point measurements were performed on a manual flash point apparatus using the Abel closed-cup method as specified in ISO 13736/IP 170 [14]. The apparatus consists of a test cup, cup cover assembly, stirrer, and heating vessel. The test cup, the cover assembly and the stirrer are made from brass. The cover assembly consists of a thermometer socket, a bush for the stirrer, and a pair of slide movement guides for supporting a test gas jet. Two flat bottomed cylindrical vessels of copper are used for the heating vessel. They are placed coaxially one inside the other and welded at their top to a flat ring. The space between them is enclosed and filled with water. The top flat ring consists of a split socket for thermometer and fiber ring fitted in the central hole for securing the test cup. The heating vessel is seated onto a cast iron tripod stand and heated by using Liquefied Petroleum Gas flame. A cooling bath is prepared by mixing chunks of solid CO_2 with water. The heating vessel is first heated or cooled below the expected flash point temperature. Then, the sample is poured in the test cup and the test cup with the cover is placed in the apparatus, the thermometer is inserted in the cup and the test flame is ignited. After that, the sample test in the cup is heated slowly (1 °C/min) and stirred continuously. The test flame is applied by slowly and uniformly opening the slide every 0.5 °C rise in temperature, until a distinct flash happens in the interior of the test cup. The temperature recorded at that point is the flash point.

2.1. Fuels used

A gasoline of 91 RON and a diesel fuel available in the Saudi Arabian market were used in the test program. The Dry Vapor Pressure Equivalent (DVPE) measured according to ASTM D5191 and the distillation characteristics measured according to ASTM D86-11b are listed in Table 1 for these two fuels. These data are also listed for some blends of these fuels in Table 1 along with the composition of the gasoline from GC analysis. The effects on volatility characteristics of blending gasoline and diesel are illustrated in Figs. 1 and 2. Fig. 1 plots the volume percent recovered against the temperature and Fig. 2 shows the DVPE plotted against the volume percent of gasoline in the dieseline (from Table 1). Fig. 2 has two additional points for gasoline volume concentrations of 15% and 85% not shown in Table 1.

Table 1
Fuel properties.

	Diesel						Gasoline
Gasoline concentration (vol.%)	0	5	10	50	90	95	100
DVPE[a] (kPa) (ASTM D5191)	<0.7	2.5	8.2	44.6	67.6	69.7	72.8
Distillation (ASTM D86-11b)							
Initial boiling point (°C)	172	31	31	31	31	31	31
5% vol recovery (°C)	194	176	132	54	46	45	45
10% vol recovery (°C)	204	200	177	63	50	50	49
20% vol recovery (°C)	223	218	208	85	58	57	56
30% vol recovery (°C)	243	241	234	122	65	64	62
40% vol recovery (°C)	261	260	255	163	74	72	70
50% vol recovery (°C)	276	275	272	206	87	83	79
60% vol recovery (°C)	290	290	288	252	106	98	93
70% vol recovery (°C)	305	305	305	285	128	119	112
80% vol recovery (°C)	323	322	325	316	149	138	131
90% vol recovery (°C)	346	347	353	362	200	161	151
95% vol recovery (°C)	363	367	367			208	166
Final boiling point (°C)	376	376	376	376	376	376	188
Composition (ASTM D5443-09)							
Normal paraffins (vol.%)							22.5
Iso paraffins (vol.%)							33.5
Olefins (vol.%)							4.5
Naphthenes (vol.%)							8.6
Aromatics (vol.%)							30.9

[a] DVPE – Dry Vapor Pressure Equivalent.

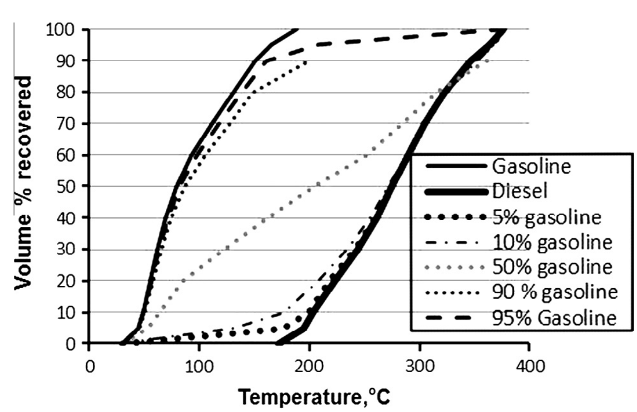

Fig. 1. Distillation characteristics from ASTM D86 for blends (from Table 1).

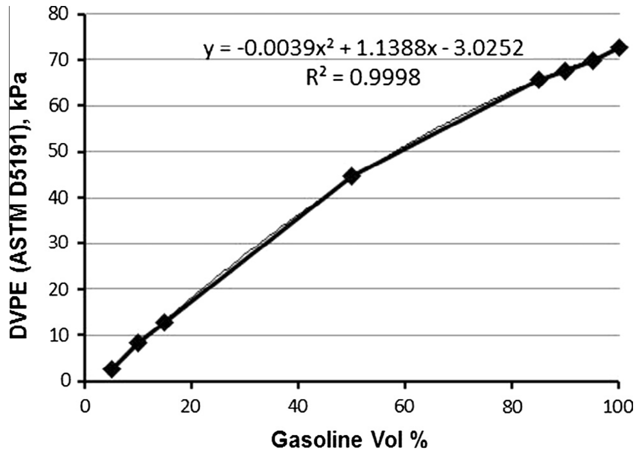

Fig. 2. Variation of DVPE with gasoline concentration of the gasoline/diesel blend.

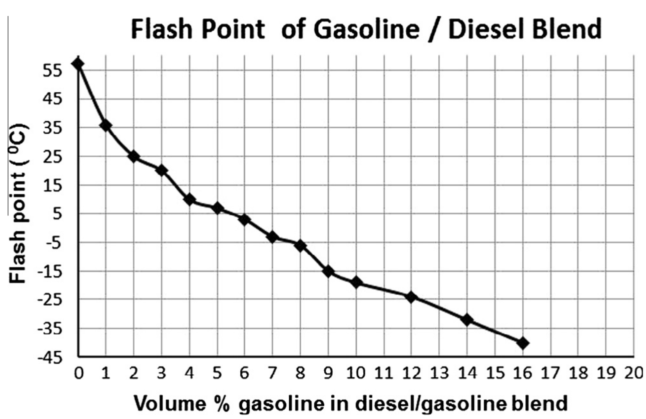

Fig. 3. Flash point of gasoline/diesel blend – IP 170, manual Abel closed-cup method.

3. Flash point results for gasoline/diesel blends

Different blends were prepared by adding gasoline to diesel in incremental steps of 1% by volume and their flash points measured. These results are shown in Fig. 3 where the first point is for pure diesel which has flash point at 57 °C. The flash point decreases sharply with increasing concentration of gasoline and reaches −40 °C at 16% volume of gasoline in the blend. Flash points below −40 °C could not be tested due to cooling bath limitations. As the temperature decreases, paraffins in the diesel fuel start crystallizing and solidifying below a limiting temperature which could be between 0 °C and −15 °C – see Chapter 2 in [2]. Other diesel components will also rapidly cease contributing to the vapor above the liquid and the flash point of the blend will rapidly approach that of gasoline – usually taken to be −45 °C [10]. It can be seen from Figs. 2 and 3 that there is an inverse relationship between DVPE and flash point. In fact a slight extrapolation from these two figures would suggest that when the DVPE reaches about 15 kPa, the blend would have the same flash point as gasoline i.e. −45 °C. The repeatability of flash point measurements is around 4 °C [15]. Even accounting for such uncertainty, Fig. 3 suggests that blends with gasoline concentration greater than 20% by volume have flash points essentially similar to that of gasoline.

4. Conclusion

Experimental results on the effects of blending a full boiling range gasoline and a diesel fuel on volatility characteristics and flash point are presented. The flash point of the blend falls very rapidly as the concentration of gasoline is increased and reaches −40 °C at a gasoline concentration of 16% by volume. This suggests that blends with gasoline concentrations greater than 50%, which would be of interest for GCI engines, will have flash points similar to that of gasoline (−45 °C) and can be considered to be as safe as gasoline for use in vehicles.

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