HUNGARIAN JOURNAL
OF INDUSTRIAL CHEMISTRY
VESZPRÉM
Vol. 39(3) pp. 349-352 (2011)

PROPERTIES OF DIESEL-ALCOHOL BLENDS

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Fuels from renewable sources such as biodiesel or bioalchohols are getting more attention also as blending components to fossil fuels and because of their less environmental impact. Stability and physico-chemical properties of different diesel-alcohol blends were investigated by different composition. The solubility properties of the alcohols are mainly dependent on the carbon chain length of the alcohol, their water content, additives, temperature and also on the hydrocarbon composition of the diesel fuel. Bio-butanol has better physic-chemical properties than bio-ethanol and its blends with diesel fuel have proper parameters, like Cold Filter Plugging Point and High Frequency Reciprocating Rig lubricity are close to those of the base diesel fuel.

Keywords: Bioalcohol, diesel-ethanol blend, diesel-butanol blend, Cold Filter Plugging Point, High Frequency Reciprocating Rig

Introduction

Diesel fuels from fossil source are widely used in automobiles and transportation vehicles because of its drivability and thermal efficiency. The strict governmental regulation on exhaust emissions and the fast depletion of worldwide petroleum reserves provide a strong encouragement to the research for alternative fuels. So fuels from renewable sources such as biodiesel or bioalchohols are getting more attention because of their less environmental impact. Mixtures of fossil fuel and biofuels are also promising. Our current investigation is focusing on the use of alcohol as a blending component in diesel fuels. The high oxygen content of the alcohols can improve the burning efficiency of the fuel blend and also can reduce emissions of the particulate matter (PM), carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxides (NO_x) [1-3]. The solubility of the alcohols depends on the temperature and also on the hydrocarbon chain length (non-polar part). Also crucial the water content of the alcohols. Especially phase separation can occur in the fuel blend if ethanol has higher water content than 1 v/v % [4, 5]. Important physical-chemical properties such as cetane number and heating value are reduced in the diesel-alcohol blends. These values can be improved by additives.

Properties of diesel-ethanol blends

The solubility of ethanol in diesel fuel mainly depends on the following factors:

- water content;
- temperature;
- hydrocarbon composition of the diesel fuel;
- additives.

The presence of ethanol causes physico-chemical changes in diesel fuel. It can significantly reduce the cetane number, heat content, viscosity, flashpoint, etc.

For example the heat content of the diesel fuel is reducing by ca. 2% if 5 v/v% ethanol is added to it. *Table 1* shows the decreasing tendency in the heat content with increasing ethanol content.

Table 1: Heat content of ternary mixtures [6]

Mixtures	**Gross heat content** (MJ/kg)
Diesel	42.35
Diesel + 10% ethanol + 1% A_1 + 1% A_2	40.98
Diesel + 15% ethanol + 1% A_1 + 1% A_2	40.75
Diesel + 20% ethanol + 1% A_1 + 1% A_2	39.59

A_1, A_2 emulsifier additives

The cetane number of the diesel-ethanol blend fuel reduces significantly, because the cetane number of ethanol is extremely low. Each 5 v/v% ethanol added to the diesel fuel, the cetane number reduced ca. 4-6 units in the diesel-ethanol blend [5]. *Fig. 1* shows the decreasing order of cetan number in the function of ethanol content.

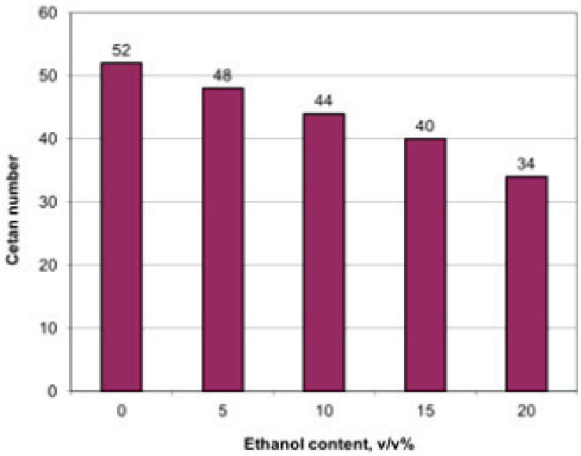

Figure 1: The change of diesel fuel cetane number in the function of ethanol content.

Therefore it is preferable to add ignition improver in order to raise the cetane number of diesel-ethanol blends. With organic nitrates (alkyl nitrates, triethilene glycol dinitrate etc.) as prefered ignition improvers the cetane number can be increased up to the level of the normal diesel fuel [7].

The hydrocarbon composition of the diesel fuel especially the aromatic content greatly affects the ethanol solubility. Reducing aromatic content of diesel fuels influences the miscibility of ethanol in diesel fuel and it affects the amount of additive required to achieve a stable blend. With the use of emulsifiers one can avoid phase separation even in case of higher ethanol concentration (≥15v/v%).

Experimetal

The diesel-butanol blends were produced by the base gas oils summarised in *Table 2*, by butanol. The concentrations of the emulsifiers and butanol were changed between the following ranges:

- emulsifiers: 0.5–2 v/v%
- butanol: 5–20 v/v%

The water content of the butanol was varied between 0 and 2 v/v%. Preparation of the blends was carried out in vials of 150 cm^3 volume. Emulsions were stirred in a laboratory shaker for 24 h. Stability of the emulsions was investigated in the temperature range (–20)–(+25) °C.

Table 2: “A”: hydrotreated gas oil with low sulphur content, “B”: Light gas oil from paraffinic crude oil (Algyő, Hungary)

Properties	“A”	“B”
Density at 15 °C, g/cm^3	0.8364	0.7971
Sulphur content, mg/kg	8	600
Nitrogen content, mg/kg	30	5
Total aromatic content (HPLC), %	32.7	13.8
Kinematic viscosity at 40 °C, mm^2/s	2.75	2.86
CFPP (Cold Filter Plugging Point), °C	-3	ca. -24
Flash point (Pensky-Martens), °C	72	52
Destillation range, °C	176–361	169–291
Cetane number	50.3	54.8
HFRR, μm	556	749

Properties of diesel-butanol blends

Using butanol instead of ethanol as a blending component in diesel-alcohol blends has several advantages. Butanol has higher heat content and higher miscibility in diesel fuel than ethanol. In diesel-butanol blends it is less susceptible to separation in the presence of water than diesel-ethanol blends because of the lower solubilities of butanol in water and water in butanol. Since its vapor pressure is much lower than of ethanol the diesel-butanol blends are potentially suitable for transport in the existing piplines and one can avoid the need for additional transportation and storage infrastructure and so extra costs.

Butanol has different isomers, based on the location of the hydroxyl group (–OH) and carbon chain structure. Butanol production from biomass tends to yield mainly straight chain molecules. Therefore in our experiments synthetic grade n-butanol was used.

In our investigation the butanol concentration was changed between the range of 5–20 v/v%. Butanol with 1 v/v% and 2 v/v% water content was also used as blending components. To avoid phase separation because of the water content emulsifier (Tween 85, Tween 80, EPILAN KCL 3. EPILAN KCL 11/90, EPILAN KP 7/90) were added in the concentration range of 1–2 v/v%.

Results of our investigation can be summarised as follows:

– Synthetic grade butanol greatly dissolves in diesel fuel at any ratio (5–20 v/v%).
– To avoid phase separation emulsifier must be added to the blends with water containing butanol to get stable blends.
– The homogenous blends have stayed stable without any phase separation by changing the temperature in the range 5–25 °C.

- In the case of winter grade diesel fuel paraffin precipitate has appeared below the temperature -15 °C, probably because butanol reduced the efficiency of the paraffin dispersant additive.
- Other not polysorbate and not fatty alcohol etoxilate based surfactants also should be tested.

The following selected stable blends were tested for the cold filter plugging point (CFPP) and high frequency reciprocating rig (HFRR) lubricity parameter *(Table 3)*. The results of the measurements are summarised in *Table 4*.

Table 3: Composition of the selected stable blends

Sample	Composition
15	85 v/v% Diesel „A" + 15 v/v% butanol with 2 v/v% water
16	80 v/v% Diesel „A" + 20 v/v% butanol with 2 v/v% water
33	89.33 v/v% Diesel „A" + 10 v/v% butanol with 2 v/v% water + 0.67 v/v% Span 80
34	86.33 v/v% Diesel „A" + 13 v/v% butanol with 2 v/v% water + 0.67 v/v% Span 80
35	84.33 v/v% Diesel „A" + 15 v/v% butanol with 2 v/v% water + 0.67 v/v% Span 80
36	79.33 v/v% Diesel „A" + 20 v/v% butanol with 2 v/v% water + 0.67 v/v% Span 80
43	95 v/v% Diesel „B" + 3 v/v% butanol with 2 v/v% water + 2 v/v% EMPILAN KCL 3
44	93 v/v% Diesel „B" + 5 v/v% butanol with 2 v/v% water + 2 v/v% EMPILAN KCL 3
45	90 v/v% Diesel „B" + 8 v/v% butanol with 2 v/v% water + 2 v/v% EMPILAN KCL 3
46	88 v/v% Diesel „B" + 10 v/v% butanol with 2 v/v% water + 2 v/v% EMPILAN KCL 3

Table 4: The Cold Filter Plugging Point (CFPP) and High Frequency Reciprocating Rig (HFRR) value of selected stable blends

	Sample	CFPP, °C	HFRR, µm
Diesel „A"	Diesel "A"	-3	556
	15	0	364
	16	1	351
	33	-1	232
	34	0	279
	35	0	263
	36	0	300
Diesel „B"	Diesel "B"	-24	749
	43	-32	266
	44	-33	289
	45	-33	311
	46	-33	281

One of the low-temperature properties the cold filter plugging point (CFPP) has changed slightly compared to the base diesel fuels, so even higher concentration of butanol has relatively minor effect on that parameter. In case of Diesel "B", CFPP values decreased definitely. The lubricity properties of diesel fuels are generally evaluated by the use of a bench test described as the High Frequency Reciprocating Rig (HFRR). The test measures the wear scar of a test specimen that is subjected to wear, using only the test fuel as lubricant. Based on the European Norm EN 590:2009 (test method ISO 12156-1) for diesel fuels all of the blends fulfill the maximum 460 µm of the HFRR value. The use of the diesel-butanol blends in diesel engines is very promising as has already reported in the literature [8].

Conclusions

The diesel-bioalcohol fuel blends are very promising fuel alternative. The solubility of diesel-alcohol blends is mostly dependent on carbon chain length of the primary alcohol and its water content. Therefore butanol seems to be more suitable for a mixing component, because it hardly dissolves in or adsorbs water. The other physico-chemical parameters (heating value, cetane number, kinematic viscosity etc.) of butanol are also much better than that of ethanol. The CFPP and HFRR values of the produced diesel-butanol blends are really promising and close to the values of a base diesel fuel. We should also investigate the possibility to use biodiesel as the third mixing component in the fuel blends [9, 10].

ACKNOWLEDGEMENT

The project TÁMOP 4.2.1/B-09/1/ KONV-2010-0003 "Mobility and Environment: Researches in the fields of motor vehicle industry, energetics and environment in the Middle-and West-Transdanubian Regions of Hungary." greatly acknowledged for the financial support.

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