Investigation of Impact of Temperature on Kinematic Viscosity of Pistacia Chinensis Oil Biodiesel and Its Blends

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Abstract

The compositions and kinematic viscosity of Pistacia Chinensis-based biodiesel (PCME) are investigated. Viscosity temperature equations are proposed for predicting kinematic viscosity of PCME and its blends with 0 petrodiesel (0PD) /-10 petrodiesel (-10PD) at different temperature. In this work, we show that PCME is mainly composed of fatty acid methyl esters of 14-24 even-numbered C atoms: $C_{14:0}$-$C_{24:0}$, $C_{16:1}$-$C_{22:1}$, $C_{18:2}$-$C_{20:2}$ and $C_{18:3}$. PCME has higher kinematic viscosity and unfavorable viscosity temperature property, its kinematic viscosity (40 °C) is 5.99 mm²/s. An approach to reduce viscosity and enhance viscosity temperature property is put forward: blending with 0 PD/-10PD.

Keywords

Biodiesel, Pistacia chinensis oil, Kinematic viscosity.

1. Introduction

The raw material of biodiesel at present is mainly animal and vegetable oils, which is probably contributed to adding the cost of biodiesel to some extent and again sting the use of biodiesel [1]. It relieves the problem of biodiesel raw material shortage that using woody plant oil to prepare biodiesel, such as Pistacia chinensis oil in china [2-3]. For the correct development of the models for the engine combustion, it is required the knowledge of the thermophysical properties of the biodiesel blends. Two important properties are density and viscosity. The viscosity is a measure of the internal friction or resistance of a substance to flow. As the temperature of the substance is increased, its viscosity decreases and it is therefore able to flow more readily. Viscosity affects the operation of fuel injection equipment, especially at low temperatures. High viscosity leads to poorer atomization of the fuel spray and less accurate operation of the fuel injectors [4-7]. In this paper, attempt has been made to investigate the impact of petrodiesel and temperature on Pistacia chinensis oil methyl ester (PCME) kinematic viscosity. It can be expected to provide some help for the selection of petrodiesel and its blending ratio that are beneficial for reducing a PCME kinematic viscosity, thus improving the atomization characteristic of a higher viscosity PCME by adding some suitable petrodiesel into it.

2. Experimental

2.1 Materials

0 petrodiesel (0PD) and -10 petrodiesel (-10PD) are purchased from China Petroleum & Chemical Corporation; PCME is prepared by our laboratory, in line with GB/T 20828-2007 requirements.

2.2 Composition analysis

Oil samples are analyzed by gas chromatography-mass spectrometer (GC-MS) (Finnigan, Trace MS, FID, USA), equipped with a capillary column (DB-WAX, 30 m × 0.25 mm × 0.25 μm). The carrier gas is helium (0.8 mL/min). The sample injection volume is 1 μL. Temperature program is started at 160 ℃, staying at this temperature for 0.5 min, heated to 215 ℃ at 6 ℃/min, then heated to 230 ℃ at 3 ℃ /min, staying at this temperature for 13 min.

2.3 Kinematic Viscosity Measured

The kinematic viscosity of oil samples is measured in accordance to GB/T 265-1988, using the SYP1003-6 Kinematic Viscosity Tester and SYP1003-7 Kinematic Viscosity Low Temperature Tester (Shanghai BOLEA Instrument & Equipment Co., Ltd., China).

3. Results and discussion

3.1 Chemical composition

The chromatogram of PCME analyzed by GC-MS is showed in Fig. 1 and the chemical compositions are showed in Table 1.

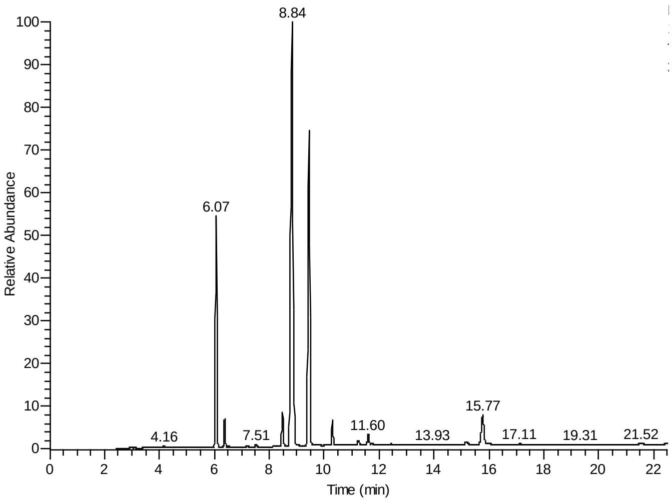


Fig. 1 The gas chromatogram of Pistacia Chinensis methyl ester

Table 1 Main chemical compositions of Pistacia Chinensis methyl ester (w)/%

PCME	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{20:0}$	$C_{22:0}$	$C_{24:0}$	$C_{16:1}$	$C_{18:1}$	$C_{20:1}$	$C_{18:2}$	$C_{18:3}$
Content	0.06	15.56	2.33	0.30	0.28	0.15	1.66	46.16	0.93	3.52	27.21

Note: $C_{m:n}$ is the shorthand of fatty acid methyl ester; *m* means the carbon number of fatty acid; *n* means the number of C=C.

From Table 1, we can see that dominate the chemical compositions of PCME is the fatty acid methyl ester composed by 14-24 even number carbon atoms, and the mass fraction of saturated fatty acid methyl esters ($C_{14:0}$~$C_{24:0}$) and unsaturated fatty acid methyl esters ($C_{16:1}$~$C_{22:1}$, $C_{18:2}$~$C_{20:2}$ and $C_{18:3}$) is 18.68% and 81.09% respectively.

3.2 Effect of temperature on kinematic viscosity of 0PD, -10PD and PCME

The kinematic viscosity (40 ℃) of PCME, 0PD and -10PD is 5.99 mm^2/s, 2.91 mm^2/s and 2.53 mm^2/s respectively, and the effect of temperature on kinematic viscosity of 0PD, -10PD and PCME are given in Fig. 2.

The kinematic viscosity of PCME is higher, almost reaches the kinematic viscosity upper limits (6.0 mm^2/s) of biodiesel standards. From Fig. 1, we can see that as the temperature is decreased, PCME viscosity increases rapidly. Thus, viscosity temperature property of PCME is poor, and the viscosity temperature equation: v_t=0.009t^2-0.771t+22.103 R^2=0.997. The viscosity affects the atomization process. Atomization is the first stage of combustion in the diesel engine. Oxygen in the air will react rapidly with fuel on the outer surface of the oil droplet and releases a tremendous amount of heat to the surrounding. This will initiate other competitive chemical reactions, such as charring or coking and polymerization. Thus, higher viscous PCME, which tend to form larger droplet size, may enhance the polymerization reaction, especially oil of high degree of unsaturation. Based on lower viscosity and good viscosity temperature property of 0PD and -10PD, an approach for reduce viscosity and enhance viscosity temperature property of PCME is blending with 0PD or -10PD.

The CFPP of PME/-10PD is showed in Fig.3. From Fig.3, the CFPP of PME/-10PD is the lowest to -11 ℃, which further supports the crystal results that blending with petrodiesel improved the cold flow properties of biodiesel.

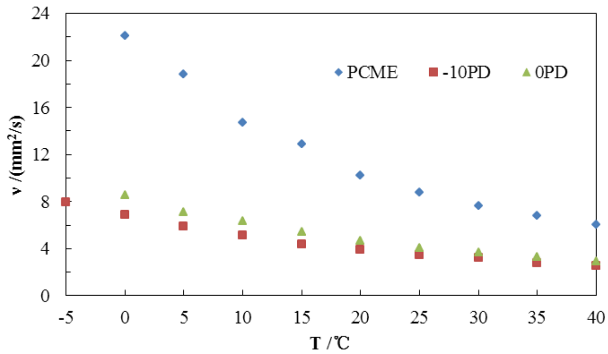
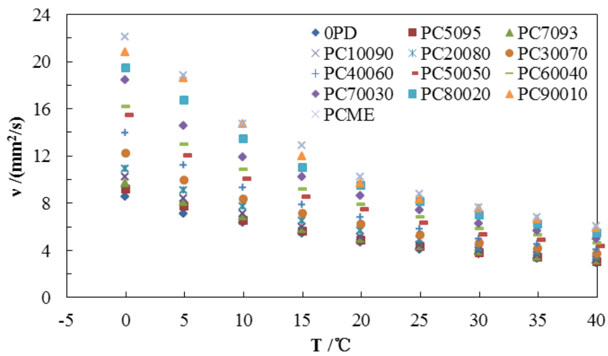


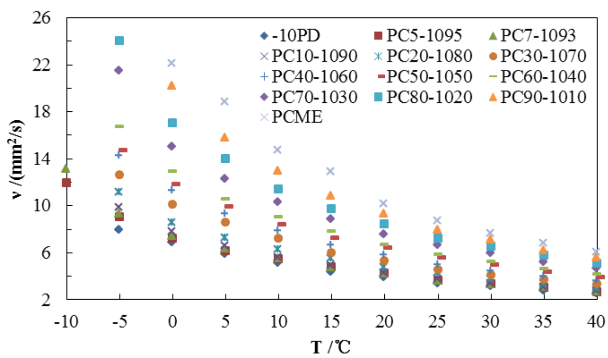
Fig. 2 The viscosity-temperature relationship of PCME, 0PD and -10PD

3.3 Effect of temperature on kinematic viscosity of PCME/0PD and PCME/-10PD

The kinematic viscosity (40 ℃) and the effect of temperature on kinematic viscosity of PCME/0PD and PCME/-10PD are given in Fig. 3.



(a) 0PD



(b) -10PD

Fig. 3 The viscosity-temperature relationship of PCME/0PD and PCME/-10PD blends

From Fig. 3, we can see that as the 0PD/-10PD ratio increases, blend oils viscosity decreases from PCME viscosity down to 0PD/-10PD. And blend also enhances viscosity temperature property, viz., as the 0PD/-10PD ratio increases, blend oils viscosity increases slowly as temperature decreases.

4. Conclusion

The above discussion shows that: PCME is mainly composed of fatty acid methyl esters of 14-24 even-numbered C atoms: $C_{14:0}$~$C_{24:0}$, $C_{16:1}$~$C_{22:1}$, $C_{18:2}$~$C_{20:2}$ and $C_{18:3}$, and the mass fraction of saturated fatty acid methyl esters and unsaturated fatty acid methyl esters is 18.68% and 81.09% respectively. The kinematic viscosity (40 ℃) of PCME is 5.99 mm^2/s. PCME has higher kinematic viscosity and unfavorable viscosity temperature property. An approach to reduce viscosity and enhance viscosity temperature property is put forward: blending with 0PD/-10PD.

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