International Conference on Applied Energy 2019
Aug 12-15, 2019, Västerås, Sweden
Paper ID: 135

Experimental studies on the thermal conductivity of methyl laurate component of biodiesel with three higher alcohols

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ABSTRACT

Biodiesel has been considered as one of the feasible attempts to replace the fossil fuels. Alcohols always played a role as the additives to improve the certain properties of biodiesel. In this work, the thermal conductivity in the liquid phase of binary mixtures of methyl laurate usually the significant biodiesel component with three higher alcohols (1-propanol, 1-butanol and 1-pentanol) was measured with the teamperature ranging within 287 K to 358 K at atmospheric pressure. The total standard uncertainty of the experimental results was estimated to be less than 2 % and the repeatability was better than ± 0.5 %. The thermal conductivity data of binary mixtures were fitted as a function of temperature, and the average absolute relative deviation and the maximum absolute relative deviation between the experimental data and calculated results were 0.08 % and 0.23 % for methyl laurate/1-propanol, 0.09 % and 0.32 % for methyl laurate/1-butanol, 0.10 % and 0.31 % for methyl laurate/1-pentanol, respectively.

Keywords: biodiesel, methyl laurate, 1-propanol, 1-butanol, 1-pentanol, thermal conductivity

1. INTRODUCTION

In recent year, the unabated depletion of the remaining reserves of conventional non-renewable fossil fuels and the excessive emissions of green-house gases caused the serious environment problems such as the global warming and air pollution [1-2]. In this case, to develop other alternative fuels becomes the new focus of many investigations. Due to several apparent reasons, biodiesel is considered as one of promising alternative fuels and has been widely explored. Firstly, biodiesel is non-sulfur content, non-toxic, being better biodegradability, lower monoxide (CO) and higher cetane number compared with diesel fuels [3-5]. Secondly, using of biodiesel can lower the emissions of greenhouse gas and reduce global warming. Thirdly, the properties such as the former presents higher flash points, good lubricity and similar specific gravity, heat of combustion and kinematic viscosity compared with fossil diesel enable the use of biodiesel and biodiesel blends in conventional diesel engines without significant modifications.

Biodiesel is the mixtures which blended by the Fatty acid methyl esters (FAME) and ethyl esters (FAEE) with even n from 8 to 24. Thermodynamic property data of FAMEs and FAEEs are particularly important for its applications in energy technologies. Thermal conductivity is an essential thermodynamic property and is necessary for the thermal design and to optimize the diesel engine[6-8].

In our research group, the high presion thermal conductivity measuremental system has been established and the thermal conductivity of eight methyl esters (methyl myristate, methyl laurate, methyl caprate, methyl pelargonate, methyl caprylate, methyl caproate, methyl pentanoate, methyl butyrate) [9,10] and five ethyl esters (ethyl myristate, ethyl laurate, ethyl caprate, ethyl caprylate and ethyl heptanoate) in the liquid phase have been measured [11]. In this work, the liquid thermal conductivity of binary mixtures with methyl laurate and three higher alcohols named 1-propanol, 1-butanol and 1-pentanol was measured with the teamperature from 287 K to 358 K at atmospheric pressure.

2. EXPERIMENTAL SECTION

2.1 Samples

Methyl laurate, 1-Propanol, 1-Butanol and 1-Pentanol used in this work were provided by Aladdin

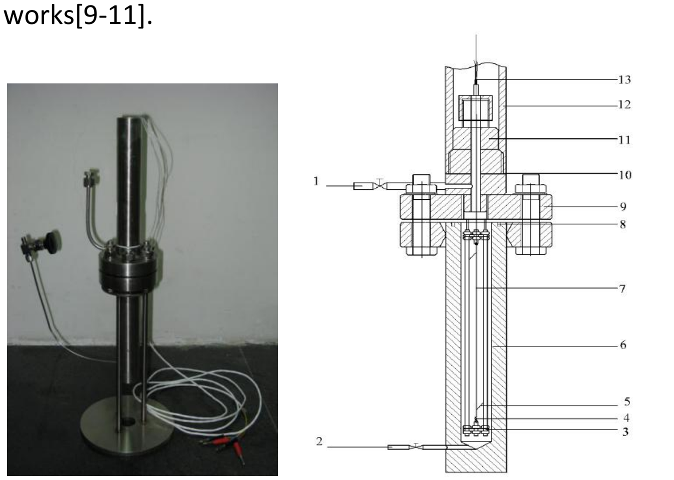
Chemistry Co. Ltd. (China). All samples, whose the mass purity was better than 0.99, were used without further purification. Table 1 shows the details of samples. The samples were not open to atmosphere during the experiment process.

Table 1. Chemical specifications

sample	CAS Number	Chemical fomular	source	Initial mass fraction purity
methyl laurate	111-82-0	CH3(CH2)10COOCH3	Aladdin	>0.99
1-Propanol	71-23-8	CH3CH2CH2OH	Aladdin	≥0.995
1-Butanol	71-36-3	CH3(CH2)3OH	Aladdin	≥0.995
1-Pentanol	71-41-0	CH3(CH2)4OH	Aladdin	>0.99

2.2 Experimental Procedure

Transient hot-wire method is one of the most accurate and reliable methods to measure the liquid thermal conductivity of fluids and have been introduced in the literatures. In our previous work, a liquid thermal conductivity experimental system has been established based on the transient hot-wire method with one bare platinum wire. Figure 1 is the photo and schematic drawing of experimental apparatus which is made from stainless steel. More information about the experimental system such as data acquisition system, temperature control system and the experimental procedure has been introduced in our published works[9-11].



1.effused pipeline 2.injected pipeline 3.PTFE framework 4.spring 5.voltage lead 6.vessel 7.platinum wire 8.Cu-O-ring 9.flange 10.PTFE O-ring 11.seal 12.steel cover 13.extension line

Figure 1 photo and schematic drawing of experimental apparatus

The estimation of the uncertainty of the thermal conductivity measurement was mentioned as below. A cathetometer was used to measure the length of the platinum wire between the potential leads with an uncertainty of 0.02 %. The temperature coefficient uncertainty of platinum wire was estimated within the range of 0.2 %, the uncertainty of heat generation of hot wire was less than 0.2 %, the uncertainty of temperature rise slope d Δ T/ dlnt of hot wire was less than 0.8 %. Moreover, the uncertainty of deviations from mathematical ideal model and that of the other modes of heat transfer was calculated, which was decreased to one small magnitude in properly designed instrument under selected operating conditions. Consequently the total standard uncertainty of the present thermal conductivity measurements for liquid was estimated to be better than 2%.

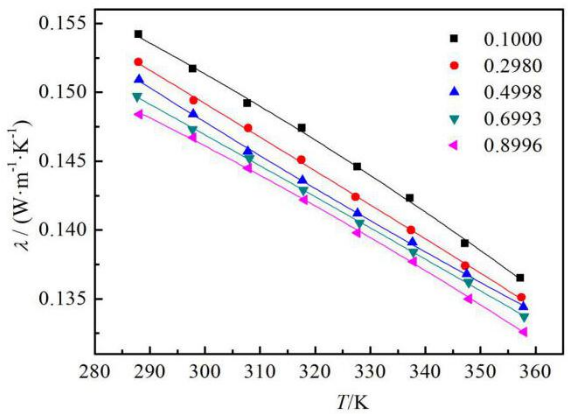
3. RESULTS

3.1 Experimental Procedure

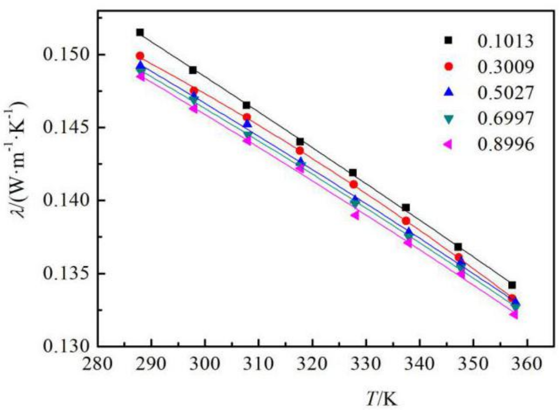
The liquid thermal conductivity of binary mixtures of methyl laurate with three higher alcohols (1-propanol, 1-butanol and 1-pentanol) was measured with the teamperature from 287 K to 358 K at atmospheric pressure. The concentrations of methyl laurate measured were 0.2002, 0.4008, 0.5998 and 0.7993 (by weight) of methyl laurate/1-propanol blends, 0.2001, 0.4001, 0.5990 and 0.8003 (by weight) of methyl laurate/1-butanol blends, and 0.1941, 0.4008, 0.6035 and 0.8002 (by weight) of methyl laurate/1-pentanol blends.

Each experimental data of the liquid thermal conductivity was measured three runs at the same temperature. In all measurements, the temperature rise of the platinum wire was about 3.0-4.0K and the measurement time was 1s after the initiation of heating by adjusting the current through the wire.

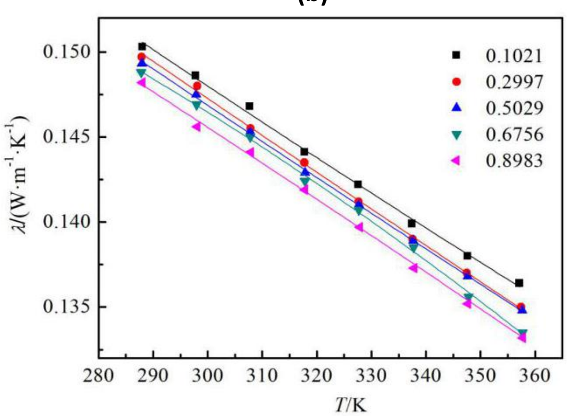
The temperature dependence of thermal conductivity for binary blends in liquid phase are displayed in Figure 2 to Figure 5. We can apparently see that the current results decrease smoothly with the increase of temperature.



(a)



(b)



(c)

Figure 2 Temperature dependence of the liquid thermal conductivity in different concentrations of methyl laurate of the blends at atmospheric pressure: (a) methyl laurate/1-propanol blends; (b) methyl laurate/1-butanol blends; (c) methyl laurate/1-pentanol blends.

Then, the liquid thermal conductivity of binary blends were correlated with temperature by a polynomial function. The equation is as follows

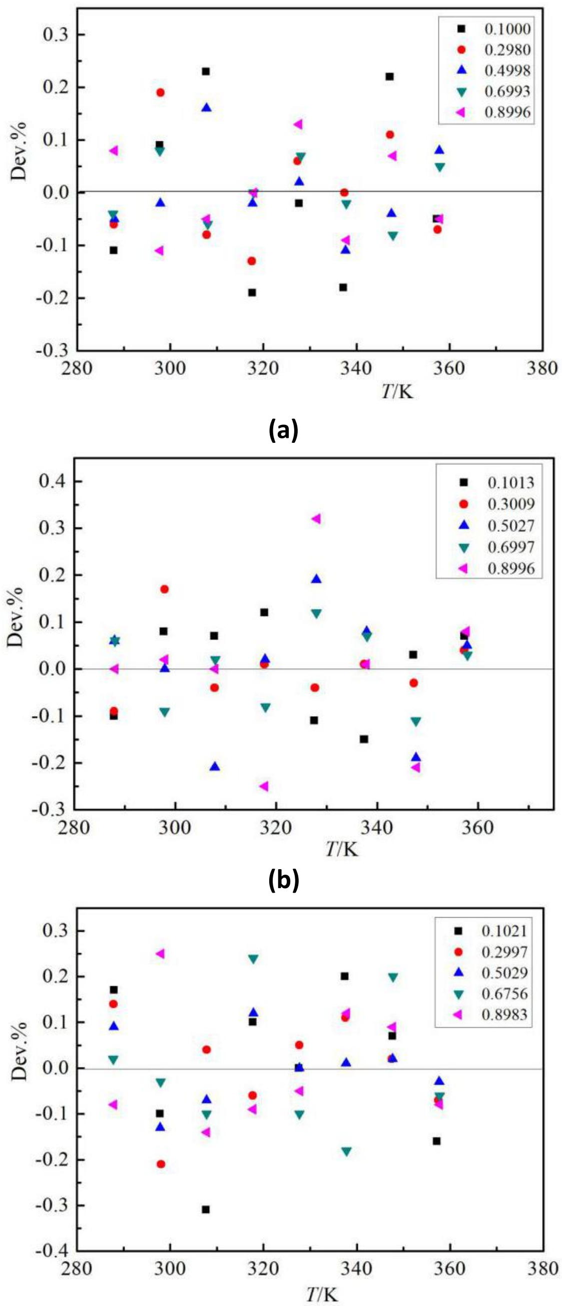
$$\lambda = \lambda_0 + bT + cT^2 \quad (1)$$

In Equation (4), the unit of thermal conductivity λ and temperature T is W·m-1·K-1 and K, respectively. Table 2 are the coefficients (λ0 , b and c) in equation (4) for methyl caprate in different concentrations of the binary blends.

Table 2 Coefficients of polynomial function for different substance (x is the mass fraction of methyl laurate)

x	λ_0/(W·m^{-1}·K^{-1})	*b*/(W·m^{-1}·K^{-2})	*c*/(W·m^{-1}·K^{-3})
Methyl laurate + 1-Propanol			
0.1000	0.17158	9.44338×10^{-5}	-5.39758×10^{-7}
0.2980	0.21575	-2.00981×10^{-4}	-6.97017×10^{-8}
0.4998	0.24643	-4.10859×10^{-4}	2.74016×10^{-7}
0.6993	0.20839	-1.86573×10^{-4}	-6.12518×10^{-8}
0.8996	0.16874	5.74115×10^{-5}	-4.42991×10^{-7}
Methyl laurate + 1-Butanol			
0.1013	0.20885	-1.62216×10^{-4}	-1.30091×10^{-7}
0.3009	0.15754	1.42127×10^{-4}	-5.87363×10^{-7}
0.5027	0.19336	-8.93497×10^{-5}	-2.21216×10^{-7}
0.6997	0.18989	-7.05551×10^{-5}	-2.49109×10^{-7}
0.8996	0.19363	-9.51292×10^{-5}	-2.13343×10^{-7}
Methyl laurate + 1-Pentanol			
0.1021	0.22183	-2.79485×10^{-4}	1.11120×10^{-7}
0.2997	0.21705	-2.47422×10^{-4}	4.93196×10^{-8}
0.5029	0.21596	-2.47558×10^{-4}	5.74041×10^{-8}
0.6756	0.16707	6.28737×10^{-5}	-4.38764×10^{-7}
0.8983	0.20098	-1.58640×10^{-4}	-6.89900×10^{-8}

Figure 3 illustrates the deviation between experimental data and the calculated results by Equation (1). The average absolute relative deviation and maximum absolute relative deviation are 0.08 % and 0.23 % for methyl laurate/1-propanol blends, 0.09 % and 0.32 % for methyl laurate/1-butanol blends, 0.10 % and 0.31 % for methyl laurate/1-pentanol blends, respectively. It is shown that the equation (4) can be used to calculate the liquid thermal conductivity of binary blends in different temperature with high precision which meet the requirement of the engineering applications.



(a)

(b)

(c)

Figure 3 Deviations of the liquid experimental thermal conductivity from the calculated results by Eq. (1): (a) methyl laurate/1-propanol blends; (b) methyl laurate/1-butanol blends; (c) methyl laurate/1-pentanol blends.

4. CONCLUSIONS

It is known that the utilization of biodiesel is a promising way to reduce fossil fuels consumption, and the accurate thermodynamic properties of biodiesel are very important for its applications in energy technologies. In this work, the liquid thermal conductivity of binary blends of methyl laurate biodiesel component with 1-propanol, 1-butanol and 1-pentanol were reported at temperatures ranging from 287 to 358K at atmospheric pressure.

ACKNOWLEDGEMENT

The authors acknowledge the financial support provided by Key Laboratory of Low-grade Energy Utilization Technologies & Systems Foundation of Ministry of Education (No. LLEUTS-201818)

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