Available online at
www.ijacskros.com

Indian
Journal of Advances in
Chemical Science

Indian Journal of Advances in Chemical Science S1 (2016) 73-76

Behavior of Physical Property of Biodiesel: Viscosity

Gaonkar Narayan[1], **R. G. Vaidya**[2]*

[1]Department of Physics, University College of Science, Tumkur University, Tumkur – 572 103, Karnataka, India. [2]Department of Studies and Research in Physics and C.E.I.E., Tumkur University, Tumkur - 572 103, Karnataka, India.

Received 31st March 2016; Revised 06th May 2016; Accepted 10th May 2016

ABSTRACT

Kinematic viscosity of biodiesel blends is investigated theoretically. We employed a new method to estimate the kinematic viscosity of biodiesel blends as a simultaneous function of temperature (T) and volume percent of blend components. The correlation parameters determined using the new method represent the rate of variation and behavior of kinematic viscosity with change in temperature and volume percent of blend. Different blend systems are considered to illustrate the prediction accuracy of the method. The detailed analysis of the estimated values and results revealed that the kinematic viscosity of biodiesel blends shows the characteristics temperature dependence of $1/T^2$ rather than 1/T.

Key words: *Renewable energy, Biofuels, Biodiesel, Kinematic viscosity.*

1. INTRODUCTION

Kinematic viscosity is one of the important physical properties of the fuel which influences the performance and efficiency of the engine. Viscosity affects the flow properties of the fuel which has the impact on the size of the droplets of the fuel during fuel injection. The higher viscosity forms the larger droplets lead to incomplete combustion of the fuel and exhaust emission become more. The biodiesel has slightly higher viscosity compared to the petroleum diesel. Therefore, the blend of biodiesel with petroleum diesel in different proportions is used in the internal combustion engines to keep the viscosity and other properties within the desired standards [1].

The kinematic viscosity of biodiesel blends is observed to vary with temperature and volume percent of the blend components. The knowledge of variation of viscosity with change in temperature and volume percent of blend components is the basic requirement to maintain the minimum standards of the fuel. It aids to the improvization in engineering of combustion and transport models associated with the fuels [2]. The study of variation of viscosity is helpful in understanding the basic physics behind the molecular interactions and momentum transfer in different fluid systems. There exist few models for the prediction of kinematic viscosity of biodiesel blends [2-7]. The models require critical properties of blend components, and they use parameter adjusted to experimental data. They demand number of experimental data for determination of adjustable parameters. The logarithmic Arrhenius model modified by Grunberg-Nissan Equation (3) is one of the widely used models to estimate the viscosity of blends at a constant temperature.

In this work, we propose two models to predict the kinematic viscosity of biodiesel blends as a function of temperature and volume percent of blends. The models require only kinematic viscosity of blend components in their pure form at any two temperatures. It avoids often employed regression fitting method. The variation of kinematic viscosities of two biodiesel binary blends is studied using the proposed models, and the prediction accuracy is analyzed statistically.

2. THEORY

In this section, we present two new models to predict the kinematic viscosity with temperature and volume percent of blend as two parameters. These models are developed by combining the Grunberg-Nissan equation and empirical equations which simultaneously relate the viscosity with temperature and blend volume percent. The widely used Grunberg-Nissan Equation (3) to predict the kinematic viscosity of biodiesel blends at a fixed temperature can be expressed in terms of volume fractions of the blend components. The expression for logarithmic kinematic viscosity is given by,

---

*Corresponding Author:
E-mail: ratnakarvaidya@gmail.com
Phone: +91-9916124740

$$\ln \mu = \nu_1 \ln \mu_1 + \nu_2 \ln \mu_2 \quad (1)$$

Where, ν_1 and ν_2, and μ_1 and μ_2 are volume fractions, and kinematic viscosities of components 1 and 2 in their pure form, respectively. Nogueira *et al.* [7] presented an empirical equation for kinematic viscosity as a function of temperature and mass fractions of blend. To develop the new models instead of mass fractions, we used volume percent. Then empirical equations become,

$$\ln \mu = A + \frac{B}{T} + CV \quad (2)$$

$$\ln \mu = A + \frac{B}{T^2} + CV \quad (3)$$

Here, T is absolute temperature, V is volume percent of blend component, A, B and C are correlation parameters.

2.1. Development of the Models

The kinematic viscosity of binary biodiesel blends is calculated using Equation (1) by picking the kinematic viscosity data of pure blend components at any two temperatures. The volume fractions are chosen arbitrarily to obtain four viscosity values by taking the combination two temperatures and two volume fractions. These estimated viscosity values are expressed in the form of Equations (2) and (3).

$$\ln \mu_{xy} = A + \frac{B}{T_x} + CV_y \quad (4)$$

$$\ln \mu_{xy} = A + \frac{B}{{T_x}^2} + CV_y \quad (5)$$

Where, μ_{xy} is viscosity of blend at temperature, T_x and volume percent V_y. Equations (4) and (5) produce two set of four correlations. Using these correlations, the correlation parameters are calculated and used to estimate the kinematic viscosity of biodiesel blends.

2.2. Statistical Analysis

To check the validity and to compare the reliability of the models, the standard estimate of error (SEE) and absolute average deviation (AAD) are determined. The expressions for SEE and AAD are as follows:

$$\mathrm{SEE} = \sqrt{\frac{\sum_{i=1}^{n} (X_i - Y_i)^2}{n - p}} \quad (6)$$

$$\mathrm{AAD}(\%) = \frac{100}{n} \sum_{i=1}^{n} \frac{|X_i - Y_i|}{X_i} \quad (7)$$

Where, X_i and Y_i are experimental and predicted values, n is number of data points used in the study and p is the number of parameters in the equation. Lower values of SEE and AAD indicate the better accuracy in the prediction model.

3. RESULTS AND DISCUSSION

We have studied the variation of kinematic viscosity of four biodiesel binary blend systems employing new models. Table 1 shows the experimentally measured data of kinematic viscosity of blend components at two different temperatures are tacked out from the literature for determination of correlation parameters and are used to predict the kinematic viscosity of biodiesel blends as a simultaneous function of temperature and volume percent of blend. The correlation parameters signify the rate of variation of viscosity of blends with change in temperature and volume percent of biodiesel in the blend. (Figure 1)

Table 2 shows the correlation parameters determined using the proposed models. These correlation parameters represent the rate of change of kinematic viscosity of biodiesel blends. A higher value of B and C signify the higher rate of variation of kinematic viscosity with respect to change of temperature and volume percent of blend, respectively. The comparison between two blend systems shows that the vegetable oil biodiesel undergoes a higher rate of decrease in viscosity with a small increase in temperature. The increase in temperature increases the kinetic energy of the molecules and the momentum transfer between molecules dominates over the intermolecular attraction. Therefore, the kinematic viscosity decreases. The addition of vegetable oil biodiesel to the blend increases the viscosity by higher rate compared to the soybean biodiesel. The low SEE and AAD values support the prediction capability of the models. The careful analysis of the SEE and

Table 1: The kinematic viscosity data tacked out from the literature.

Blend components	Kinematic viscosity of blend components ($mm^2.s^{-1}$)	
	T_1=293.15 K	**T_2=373.15 K**
Vegetable oil biodiesel [5]	12.32	2.35
ULSD [5]	4.19	1.14
Soybean biodiesel [7]	6.4872	1.9471
Diesel [7]	3.8433	0.9207

ULSD=Ultra low sulfur diesel

Table 2: The correlation parameters, NDP, SEE and AAD values.

Biodiesel blend system	Model	Correlation parameters			Number of data points	SEE	AAD (%)
		A	B	C			
Vegetable oil biodiesel+ULSD [6]	Equation (4)	−5.4315	2022.67	9.010×10^{-3}	54	0.143	2.76
	Equation (5)	−2.3959	332066.98	9.010×10^{-3}	54	0.118	1.86
Soybean biodiesel+Diesel [7]	Equation (4)	−4.8156	1799.75	6.362×10^{-3}	45	0.309	1.24
	Equation (5)	−2.1145	295471.61	6.362×10^{-3}	45	0.246	1.02

NDP= Number of Data Points, SEE=Standard estimate of error, AAD=Absolute average deviation

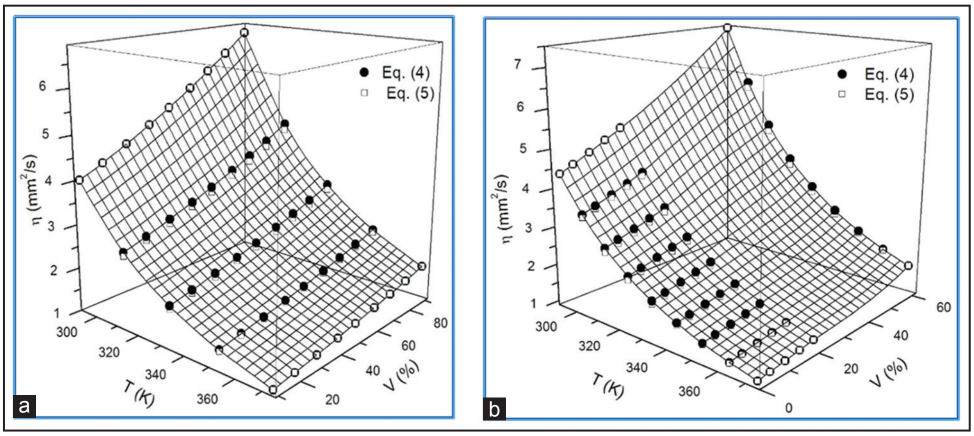

Figure 1: The variation of kinematic viscosity as a function of temperature and blend percent. The comparison of experimental data with predicted values by Equations (4) and (5), (a) Vegetable oil biodiesel + ultra-low sulfur diesel, (b) soybean biodiesel + diesel.

AAD indicates that the viscosity variation depends on $1/T^2$ rather than 1/T. The dependence of viscosity on temperature varies with nature of the molecules of the fluid. The characteristic temperature dependence of kinematic viscosity is $1/T^2$ for biodiesels which contain long chain fatty acids of methyl and ethyl esters. The similar results were obtained from the experimental measurements by several researchers related to the temperature dependency of kinematic viscosity of biodiesel.

4. CONCLUSION

We proposed two new models to estimate the kinematic viscosity of binary biodiesel blends as a simultaneous function of temperature and volume percent of blend. The correlation parameters determined using the proposed models represent the rate of variation of viscosity with change in temperature and volume percent of the blends. The vegetable oil biodiesel blend shows a higher rate of variation of kinematic viscosity compared to other. The low values of SEE and AAD for both models indicate the accuracy in prediction of kinematic viscosity. The characteristic dependence of kinematic viscosity of biodiesel blends is $1/T^2$.

5. ACKNOWLEDGMENTS

This work is supported by University Grants Commission, New Delhi, India.

6. REFERENCES

1. S. Baroutian, K. Shahbaz, F. S. Mjalli, M. A. Hashim, I. M. Al-Nashef, (2012) Densities and viscosities of binary blends of methyl esters + ethyl esters and ternary blends of methyl esters + ethyl esters + deiesel fuel from T = (293.15 to 358.15) K, ***Journal of Chemical and Engineering Data,* 57:** 1387-1395.
2. S. Kumar, J. S. Yadav, V. K. Sharma, W. Lim, J. H. Cho, J. Kim, I. Moon, (2011) Physico-chemical properties of *Jatropha curcas* biodiesel þ diesel fuel no. 2 binary mixture at T = (288.15 to 308.15) K and atmospheric pressure, ***Journal of Chemical and Engineering Data,* 56:** 497-501.
3. L. Grunberg, A. H. Nissan, (1949) Mixture law of viscosity, ***Nature,* 164:** 799-800.
4. R. M. Joshi, M. J. Pegg, (2006) Flow properties of biodiesel fuel blends at low temperatures, ***Fuel,* 86:** 143-151.
5. L. F. Ramírez-Verduzco, B. E. García-flores, J. E. Rodríguez-Rodríguez, A. R Jaramillo-Jacob, (2011) Prediction of the density and viscosity in biodiesel blends at various temperatures, ***Fuel,* 90:** 1751-1761.
6. G. R. Moradi, B. Karami, M. Mohadesi, (2013) Densities and kinematic viscosities in biodiesel -diesel blends at various temperatures, ***Journal of Chemical and Engineering Data,* 58:** 99-105.

7. C. A. Nogueira Jr, F. R. Carmo, D. F. Santiago, V. M. Nogueira, F. A. N. Fernandes, R. S. S. Aguiar, H. B. Sant'Ana, (2012) Viscosities and densities of ternary blends of diesel + soybean biodiesel + soybean oil, ***Journal of Chemical and Engineering Data,* 57:** 3233-3241.

***Bibliographical Sketch**

Dr. R. G. Vaidya is an Assistant Professor, Department of Studies and Research in Physics, Tumkur University, Tumkur, India. He obtained his Ph.D. from Karnatak University, Dharwad, India in 2013.