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Estimation of the refractive index of diesel fuel+biodiesel blends

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Abstract For now, biodiesel is the commonly accepted biofuel as a substitute for diesel fuel in internal combustion engines. Diesel fuel blends with up to 20% biodiesel can be used in diesel engines without any modification. A lot of studies regarding diesel fuel+biodiesel blends properties are presented in the literature. Some of the important properties of diesel fuel+biodiesel blends can be evaluated from other blends properties. For example, density and viscosity of biodiesel blends can be predicted based on blend refractive index. More than that, refractive index can be used as a reliable physical property to predict transesterification reaction progress. As a result, the refractive index of diesel fuel+biodiesel blends is important in order to characterize these blends or to monitor the evolution of transesterification process of vegetable oils or animal fats. The refractive index of diesel fuel+biodiesel blends can be experimentally determined or evaluated based on refractive indices of diesel fuel and biodiesel. The aim of this study was to estimate the accuracy of refractive index of diesel fuel +biodiesel blends calculation, using models initially proposed to evaluate the refractive index of a binary liquid mixture. It was shown that the refractive index of diesel fuel+biodiesel blends can be accurately predicted from refractive indices of the components of the blend. Wiener, Heller and Edward equations can be recommended to predict with a great accuracy the refractive index of diesel fuel+biodiesel blends.

Keywords: Biodiesel, diesel fuel, refractive index, models.

1. Introduction

Biofuel market is continuously growing as a result of alternative fuels benefits compared to fossil fuels: reduced environment pollution, renewable character, diversified raw materials and biodegradability. For now, biodiesel is the commonly accepted biofuel as a substitute for diesel fuel in internal combustion engines. Diesel fuel blends with up to 20% biodiesel can be used in diesel engines without any modification.

A lot of studies regarding diesel fuel+biodiesel blends properties are presented in the literature [1-14]. Some of the important properties of diesel fuel+biodiesel blends can be evaluated from other blends properties. For example, density and viscosity of biodiesel blends can be predicted based on blend refractive index [15] using a linear or respectively polynomial equation:

$$\rho_b = \alpha \cdot n_{D,b} + \beta \quad (1)$$

$$\eta_b = A \cdot n_{D,b}^2 + B \cdot n_{D,b} + C \quad (2)$$

where ρ_b, η_b, $n_{D,b}$ represent density, viscosity and respectively refractive index of the blend; α, β, A, B, C - regression coefficients.

More than that, refractive index can be used as a reliable physical property to predict

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transesterification reaction progress [16]. As a result, the knowledge of refractive index of diesel fuel+biodiesel blends is important in order to characterize these blends or to monitor the evolution of transesterification process of vegetable oils or animal fats. The refractive index of diesel fuel+biodiesel blends can be experimentally determined or evaluated based on refractive indices of diesel fuel and biodiesel.

The aim of this study was to estimate the accuracy of refractive index of diesel fuel +biodiesel blends calculation using three models initially proposed for pure components.

2. Experimental

Diesel fuel used in this study was supplied by a local company. Biodiesel was synthesized in the laboratory as presented in [17]. Some properties of these fuels used in the measurements are presented in **Table 1.** Blends of diesel fuel with biodiesel were prepared at room temperature by volume fractions, over the entire composition range with an increasing step of 0.05. The experimental uncertainty in volume fraction was estimated to be less than ±0.002.

An Atago 3T refractometer was used to measure the refractive index of diesel fuel+biodiesel blends. The refractometer was connected to a thermostated bath. The accuracy of refractive index data was of 10^{-4} and the thermostated bath had an accuracy of ± 0.05 K. The measurements were made at 298.15, 303.15, 313.15 K and 323.15 K. All measurements at each temperature were repeated three times, and the results were averaged.

Table 1. Properties of fuels used in this study

Property	diesel fuel	biodiesel
Sulfur content, mg/kg	0.14	0.00
Flash point, °C	60	140
Density at 20°C, g/cm^3	0.8414	0.8840
Refractive index at 25°C	1.4650	1.4548
Methylic esters of fatty acids % (w/w)	3.0	96.5

3. Results and Discussions

Experimental refractive index values for diesel fuel+biodiesel blends for temperature ranging from 298.15 K to 323.15 K were previously published [16].

Refractive indices of diesel fuel+biodiesel blends were evaluated using three equations:

Wiener:

$$\frac{n_{D,b}^2 - n_{D,1}^2}{n_{D,b}^2 + 2n_{D,1}^2} = x_2 \frac{n_{D,2}^2 - n_{D,1}^2}{n_{D,2}^2 + 2n_{D,1}^2} \quad (3)$$

Heller:

$$\frac{n_{D,b} - n_{D,1}}{n_{D,1}} = \frac{3}{2} x_2 \left(\frac{m^2 - 1}{m^2 + 2} \right) \quad m = n_{D,2} / n_{D,1} \quad (4)$$

and Edwards:

$$\frac{n_{D,b} - 1}{n_{D,b}} = x_1 \frac{n_{D,1} - 1}{n_{D,1}} + x_2 \frac{n_{D,2} - 1}{n_{D,2}} \quad (5)$$

where $n_{D,b}$ represents the refractive index of the mixture; $n_{D,1}$, $n_{D,2}$ – refractive indices of pure components; x_1, x_2 – molar fraction of the components in the mixture.

The equations (3), (4) and (5) were initially proposed to evaluate the refractive index of a binary liquid mixture, from the refractive indices of the pure components. Taking into account that diesel fuel is a mixture of hydrocarbons, and biodiesel is a mixture of esters, diesel fuel+biodiesel mixtures can be considered as pseudo-binary mixtures [14]. When applying these equations to diesel fuel+biodiesel blends, volume fractions were used instead of molar fractions, to express blend composition.

The predictive capacity of eq. (3), (4) and (5) to estimate the refractive index of diesel fuel+biodiesel blends was evaluated with the absolute average deviation, calculated with the eqation:

$$AAD = \frac{100}{m} \sum_{i=1}^{m} \left| \frac{n_{\exp,i} - n_{calc,i}}{n_{\exp,i}} \right| \quad (6)$$

where n_{exp} represents the experimental value of refractive index of diesel fuel+biodiesel blends, n_{calc}

– calculated value of refractive index of diesel fuel+biodiesel blends, m – number of experimental data.

Table 2 presents the AAD errors for predictive Wiener, Heller and Edwards models (eq. 3, 4 and 5) for temperature ranging from 298.15 K to 323.15 K. The accuracy of the tested models is very good, the AAD values being under 0.008%.

Table 2. AAD errors for predictive Wiener, Heller and Edwards models applied to diesel fuel+biodiesel blends

T, K	equation		
	Wiener	Heller	Edwards
	AAD %	AAD %	AAD %
298.15	0.00714	0.00713	0.00660
303.15	0.00271	0.00290	0.00300
313.15	0.00343	0.00368	0.00391
323.15	0.00602	0.00628	0.00660

Wiener, Heller or Edwards equations can be used with very good results to predict the refractive index of diesel fuel+biodiesel blends based on refractive index of the components of the blend.

4. Conclusions

Refractive index of diesel fuel+biodiesel blends is an important characteristic of these blends. Some properties of diesel fuel-biodiesel blends, like density and viscosity, can be predicted based on blend refractive index, and the evolution of transesterification process can be also evaluated based on refractive index of the blend.

This study has shown that the refractive index of diesel fuel+biodiesel blends can be accurately predicted from refractive indices of the components of the blend. Wiener, Heller and Edwards equations can be recommended to predict with a great accuracy the refractive index of diesel fuel+biodiesel blends.

5. References

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