Viscosity for palm based biodiesel and petro-diesel Blends

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ABSTRACT

From the study, the pure palm oil based biodiesel is not suitable to use as fuel in existing petro-diesel engine without any modifications. Therefore, the palm based biodiesel is blended with commercially available petro-diesel. Biodiesel is potential alternative for the currently conventional petro-diesel. Blend behavior is analyzed using various properties like density, viscosity, calorific value, refractive index, flash point, cetane number, carbon residue, as per ASTM standard operating procedure. Viscosity is important flow property for pumping of fuel in petro-diesel engine, so it is beneficial to develop correlation for viscosity at entire biodiesel volume fraction range.

In present study, viscosity is examined at various temperatures (298 K, 303 K, 313 K, 323K, 333 K) for the different blends of palm based biodiesel to the petro-diesel, For the various proportion of biodiesel B0, B05, B10, B15, B20, B25, B30, B35, B40, B45, B50, B60, B80 and B100. Using Anton Parr Rheometer MCR-52. The data is obtained and studied for estimation of empirical equation. Empirical equation is developed and compared with the equations like Kay equation, Newton equation, Dale-Gladstone equation, Eykman equation which are available in literature and the accuracy of calculated values using these models was calculated by root mean square prediction difference method (RMSPD).

Key words: *Biodiesel Blend, viscosity, temperature*

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1. Introduction

From vegetable oils and animal fat through transesterification process in presence of catalyst the reaction takes place for triglycerides and mono alcohol to produce biodiesel (monoester) and glycerine as by-product. The use of biodiesel blend with petro diesel is an emerging alternative source for the conventional diesel fuel. Biodiesel is defined as a mixture of mono-alkyl esters of saturated and unsaturated fatty acid [1].

It is advantageous to use biodiesel as fuel as it will reduce the pollution. Bio-fuels are renewable resource. We can utilize the alternative fuel without extra or no modifications in the current diesel engine. Depending upon feedstock, vegetable oil and mono alcohol, the properties are highly influenced. Before the commercial use of these blends, we need to understand the behavior of the blend with the parameters variations. Behavior of the blend can be estimated with the determination of the various properties like density, viscosity, flash point, pour point, refractive index, carbon residue, Calorific value, etc [2,3].

Palm oil, an oleaginous tropical plant, has the highest oil productivity per unit of land on earth. In terms of its usage, palm oil has various uses as a food, (oils, margarines, bread, mayonnaise, feeds, ice cream, cookies etc), in industry (soap, lubricants, detergents, plastics, cosmetics, rubber etc), in steel making, the textile industry, pharmacology etc [3,7].

Palm oil blended diesel has emerged as an alternative fuel for an internal combustion engine satisfying certain criteria, such as requiring minimum engine modification, offering uncompromised engine life and not being hazardous to human health and the environment during production, transportation, storage and utilization. Direct use of crude palm oil has been shown feasible in the engine [2,3].

Viscosity is an important property of fuel for compression ignition engines. It is worth noting that fuel viscosity increases with the increase in the percentage of biodiesel in the blend. Reheating of biodiesel before injection could be done to overcome the problem of higher fuel viscosity by taking advantage of the high temperature of the engine exhaust gas [4].

In the present study we have discussed the viscosity for the binary mixture of the biodiesel with petro-diesel blends. The experimental data has been generated. With the present study we have developed the empirical equation which can predict the viscosity of the biodiesel with dependence on volume fraction of biodiesel. To the best of our knowledge, few data were presented in literature regarding viscosity of palm based biodiesel and its blend [8-10].

The experimental data was utilized to verify the predictive capacity of different proposed equations:

Kay equation [9,10]:

$$\mu_m = v_1 D_1 + v_2 D_2 - - - - - - - - (1)$$

Newton equation [9,10]:

$$\mu_m^2 - 1 = \sum_{i=1}^{n} \{vi(D_i^2 - 1)\} - - - - - - (2)$$

Dale-Gladstone equation [9,10]:

$$\mu_m - 1 = \sum_{i=1}^{n} \{vi(Di - 1)\} - - - - - - (3)$$

Eykman equation [9,10]:

$$\frac{\mu_m - 1}{\mu_m + 0.4} = \sum_{i=1}^{n} \left(vi \times \frac{Di - 1}{Di + 0.4}\right) - - - - - - (4)$$

μ_m=density of a mixture

V_1=volume fraction of petrol-diesel

V_2= volume fraction of palm based bio diesel

D_1= viscosity of a petro-diesel

D_2= viscosity of palm based bio diesel

The accuracy of predictive models was estimated with Root Mean Square Prediction Difference (RMSPD) [9,10].

$$RMSPD = 100 \times \sqrt{\frac{1}{n} \times \sum_{i=1}^{n} \left[\frac{Y_{Cal,i} - Y_{exp,i}}{Y_{exp,i}}\right]^2} - - - - - - (5)$$

Where, Y_{Cal} and Y_{exp} are the calculated and experimental values respectively, and n is the no. of experimental data.

2. Materials:

For the current study, we have analyzed the samples of biodiesel based on palm based bio diesel. The biodiesel is mixed with the petro-diesel with different proportions. The palm based biodiesel is obtained from the supplier whereas the diesel is obtained from the local supplier.

3. Experimental work:

3.1 Viscosity:

It is measured using Anton Parr Rheometer MCR 52. The sample of 60 ml is inserted in the sampling crucible. The rotating float was inserted in the crucible. The heating is done with the external oil heating system. The sample was allowed to get equilibrium at the given temperature. For current biodiesel petro diesel blend viscosity was experimented at constant shear rate. Number of set point was taken as the constant points. For each sample reading were taken at 298 K, 303 K, 313 K, 323 K and 333 K.

4. Results and discussions:

Table 1: Experimental value of palm based biodiesel blend

Viscosity (cP)					
Blend	**298 K**	**303 K**	**313 K**	**323 K**	**333 K**
B00	3.01	2.84	2.51	2.24	1.98
B05	3.09	2.92	2.60	2.33	2.05
B10	3.20	3.01	2.72	2.43	2.18
B15	3.28	3.15	2.85	2.54	2.33
B20	3.39	3.27	2.97	2.66	2.45
B25	3.48	3.38	3.12	2.78	2.54
B30	3.59	3.47	3.25	2.90	2.67
B35	3.68	3.56	3.36	3.02	2.79
B40	3.80	3.65	3.48	3.15	2.91
B45	3.88	3.74	3.60	3.28	3.02
B50	3.96	3.83	3.71	3.42	3.12
B60	4.09	3.98	3.87	3.63	3.36
B80	4.33	4.24	4.15	3.94	3.78
B100	4.55	4.45	4.34	4.23	4.10

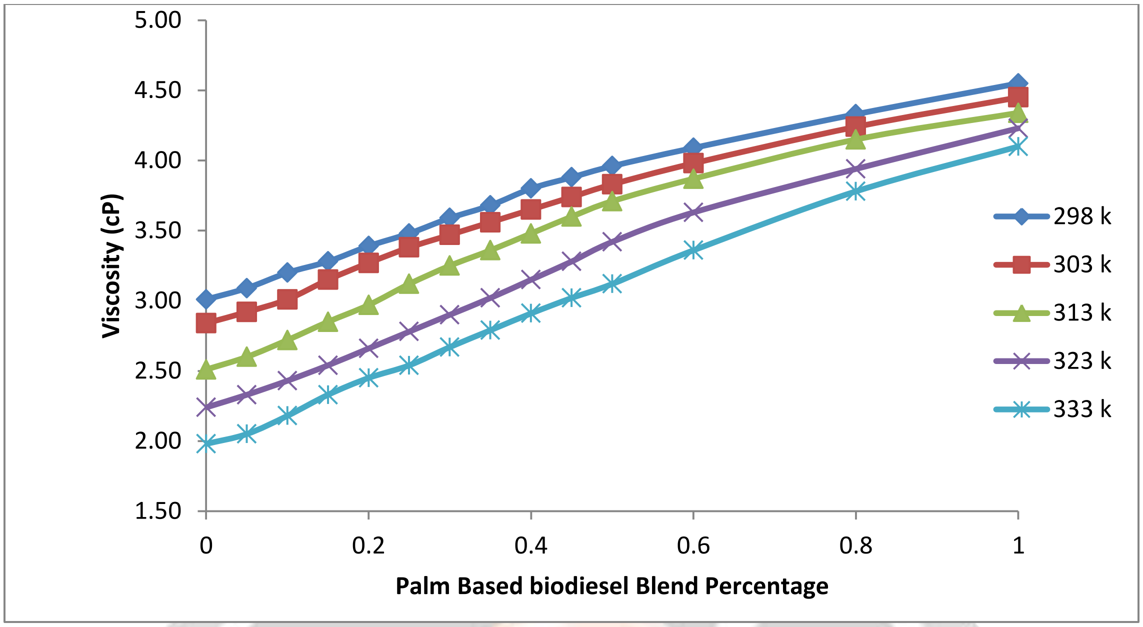

Fig-1: Viscosity of blend at different temp.

The experimental values were utilized to verify the predictive capacity of models as presented in Table 2 to Table 6.

Table 2: Viscosity using various models at 298K

Blends	Expt. Value (cP)	Calculated Values of Viscosity using equations (cP)			
		[1]	[2]	[3]	[4]
B00	3.01	3.01	3.01	3.01	3.01
B05	3.09	3.087	3.10	3.087	3.05
B10	3.20	3.164	3.19	3.164	3.10
B15	3.28	3.241	3.28	3.241	3.14
B20	3.39	3.318	3.37	3.318	3.19
B25	3.48	3.395	3.45	3.395	3.25
B30	3.59	3.472	3.54	3.472	3.30
B35	3.68	3.549	3.62	3.549	3.36
B40	3.80	3.626	3.70	3.626	3.42
B45	3.88	3.703	3.78	3.703	3.49
B50	3.96	3.78	3.85	3.78	3.55
B60	4.09	3.934	4.00	3.934	3.70
B80	4.33	4.242	4.28	4.242	4.06
B100	4.55	4.55	4.55	4.55	4.55
RMSPD (%)		**2.9002**	**1.4558**	**2.9002**	**6.8777**

Table 3: Viscosity using various models at 303 K

Blends	Expt. Value (cP)	Calculated Values of Viscosity using equations (cP)			
		[1]	[2]	[3]	[4]
B00	2.84	2.84	2.84	2.84	2.84
B05	2.92	2.92	2.94	2.92	2.88
B10	3.01	3.00	3.03	3.00	2.93
B15	3.15	3.08	3.13	3.08	2.97
B20	3.27	3.16	3.22	3.16	3.02
B25	3.38	3.24	3.31	3.24	3.08
B30	3.47	3.32	3.40	3.32	3.13
B35	3.56	3.40	3.48	3.40	3.19
B40	3.65	3.48	3.57	3.48	3.26
B45	3.74	3.56	3.65	3.56	3.32
B50	3.83	3.64	3.73	3.64	3.39
B60	3.98	3.80	3.88	3.80	3.54
B80	4.24	4.12	4.17	4.12	3.92
B100	4.45	4.45	4.45	4.45	4.45
RMSPD (%)		**3.3982**	**1.6597**	**3.3982**	**8.0221**

Table 4: Viscosity using various models at 313 K

Blends	Expt. Value (cP)	Calculated Values of Viscosity using equations (cP)			
		[1]	[2]	[3]	[4]
B00	2.51	2.51	2.51	2.51	2.51
B05	2.60	2.60	2.63	2.60	2.55
B10	2.72	2.69	2.74	2.69	2.60
B15	2.85	2.78	2.86	2.78	2.65
B20	2.97	2.87	2.96	2.87	2.70
B25	3.12	2.96	3.07	2.96	2.75
B30	3.25	3.05	3.17	3.05	2.81
B35	3.36	3.15	3.26	3.15	2.87
B40	3.48	3.24	3.36	3.24	2.94
B45	3.60	3.33	3.45	3.33	3.01
B50	3.71	3.42	3.54	3.42	3.08

B60	3.87	3.60	3.71	3.60	3.25
B80	4.15	3.97	4.04	3.97	3.68
B100	4.34	4.34	4.34	4.34	4.34
RMSPD (%)		**4.9135**	**2.5021**	**4.9135**	**11.4386**

Table 5: Viscosity using various models at 323 K

Blends	**Expt. Value (cP)**	**Calculated Values of Viscosity using equations (cP)**			
		[1]	**[2]**	**[3]**	**[4]**
B00	2.24	2.24	2.24	2.24	2.24
B05	2.33	2.33	2.37	2.33	2.28
B10	2.43	2.43	2.51	2.43	2.32
B15	2.54	2.53	2.63	2.53	2.37
B20	2.66	2.63	2.75	2.63	2.43
B25	2.78	2.73	2.86	2.73	2.48
B30	2.90	2.83	2.97	2.83	2.54
B35	3.02	2.93	3.08	2.93	2.60
B40	3.15	3.03	3.18	3.03	2.67
B45	3.28	3.13	3.28	3.13	2.74
B50	3.42	3.23	3.38	3.23	2.82
B60	3.63	3.43	3.56	3.43	2.99
B80	3.94	3.83	3.91	3.83	3.46
B100	4.23	4.23	2.24	4.23	4.23
RMSPD (%)		**2.8551**	**2.2597**	**2.8551**	**11.4739**

Table 6: Viscosity using various models at 333 K

Blends	**Expt. Value (cP)**	**Calculated Values of Viscosity using equations (cP)**			
		[1]	**[2]**	**[3]**	**[4]**
B00	1.98	1.98	1.98	1.98	1.98
B05	2.05	2.08	2.13	2.08	2.02
B10	2.18	2.19	2.28	2.19	2.06
B15	2.33	2.29	2.41	2.29	2.11
B20	2.45	2.40	2.54	2.40	2.16
B25	2.54	2.51	2.67	2.51	2.21
B30	2.67	2.61	2.79	2.61	2.27
B35	2.79	2.72	2.90	2.72	2.33
B40	2.91	2.82	3.01	2.82	2.40

B45	3.02	2.93	3.11	2.93	2.47
B50	3.12	3.04	3.21	3.04	2.55
B60	3.36	3.25	3.41	3.25	2.72
B80	3.78	3.67	3.77	3.67	3.22
B100	4.10	4.1	4.1	4.1	4.1
RMSPD (%)		**2.0830**	**3.4949**	**2.0830**	**13.1882**

With the increase in temperature, the viscosity of biodiesel-diesel blend decreases.

From the current experimental study, we have developed the correlation for the temperature and volume fraction of biodiesel to the Viscosity. The correlation can be utilized to determine the viscosity of biodiesel at any temperature and any volume fraction of biodiesel mixture at any degree of blending.

The correlation for prediction of Viscosity for binary biodiesel blend is [6]:

$$\ln \mu_m = -2.7103 + 3.5967 \times v_1 + \frac{1148.6}{T} - \frac{945.71 \times v_1}{T} - - - - - - - - - (6)$$

μ_m is the Viscosity of blend
v_1 is the volume fraction of biodiesel,
T is absolute temperature.

Table 7: RMSPD for correlation as per equation (6)

Temperature, K	298	303	313	323	333
RMSPD (%)	**2.5420**	**2.8128**	**4.3597**	**3.4988**	**3.7066**

The accuracy of the prediction is evaluated and the error is calculated as Root Mean Square Prediction Difference (RMSPD). The maximum error registered was 3.7066%. We can say that from the RMSPD data of literature correlation and correlation derived from experimental data with increase in temperature the predicted values for viscosity using correlation error also increased, therefore these correlations can be used for prediction of viscosity up to 373 K.

5. Conclusion

From the present study it was found that with increase in the volume fractions of biodiesel in the blends the viscosity of the blends increase and with increase in the temperature the viscosity of blends was decrease. Also from the experimental data we developed correlation for prediction of the viscosity of different blends and at different temperature and compare with literature correlation and measure the accuracy of correlation using RMSPD equation. we can say that from the RMSPD data of literature correlation and correlation derived from experimental data with increase in temperature the predicted values for viscosity using correlation error also increased, therefore these correlations use for prediction of viscosity up to 373 K. Viscosity is use to determine the optimum blend ratio for palm based biodiesel petro-diesel blend.

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7. References

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