Estimation of Mathematical Correlation for Flash Point and Calorific Value for Blend of Biodiesel and Petro-Diesel

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Abstract: With always increasing fuel energy demands it is mandatory to find out alternate fuel for engine run. The biodiesel is the potential alternative fuel. As it needed to blend with the petro-diesel for the use in currently working diesel engine, the behavior of the blend is needed to study. For the current study purpose flash point and heating values were studied and correlations were developed. The correlation found to give high accuracy result with a variable. The developed correlation was compared with the models for the property prediction of mixture such as Kay's equation, Newton Model, Eykman equation, Dale-Gladston Equation and Lorrentz-Lorren Equation.

Keywords* — *Biodiesel Blend, Calorific Value, Correlation, Flash Point.

I. INTRODUCTION

It is observe that the reservoir quantity of conventional fuel is decreasing very rapidly. With increase in world energy consumption every day it is mandatory finding the potential energy alternative sources and optimize for the most suitable for the currently working system [1]. Biodiesel was found to be renewable energy source for the supply of the energy as diesel fuel. The property changes according to the source of the biodiesel produced. But it was observed that the pure biodiesel can't be use directly in the currently working internal combustion engine [2]. The higher viscosity causes the ignition delayed which gives lesser knocking characteristics than the required [3]. So the blending of biodiesel with petro-diesel is the area that can be explore for the study and effective utilization of the natural resources can be done [4].

Biodiesel can be manufacture from the animal oil and the vegetable oil root. The vegetable oil based biodiesel generally made up from the vegetable oils such as sunflower oil, rapeseed oil, Jatropha oil, Karanja oil etc. [5] The use of vegetable is more practical as vegetable is renewable resource[6,7]. This vegetable oil based biodiesel have properties based on the fatty acids contains in their seeds/fruits [8]. Biodiesel known as the methyl ester of fatty acids are produced from the transesterification process [2,9]. The origin of the seeds will have higher effect on the biodiesel properties [10]. So it is important to study the property behavior and its effect on the engine performance for the different blend ratio.

II. MATERIAL

2.1 Material

For the current study purpose the biodiesel was blended with the market grade diesel. The Blending was taken in the volume percentage of biodiesel in the mixture of the Jatropha based biodiesel and petro-diesel. The samples were prepared such as B00, B05, B10, B15, B20, B25, B30, B35, B40, B45, B50, B55, B60 B65, B70, B75, B80, B85, B90, B95 and B100. [11]

Vegetable oils have high molecular weights in the range of 600–900, which are three or more times higher than diesel fuels.[12] The volumetric heating values of these oils are in the range of 39–40 MJ/kg, which are low, compared to diesel fuels (about 45 MJ/kg).[13] The presence of chemically bound oxygen in vegetable oils lowers their heating values by about 10%. The cetane numbers are in the range of 34–42. [14] The cloud and pour points of vegetable oils are higher than that of diesel fuels. [15]

2.2 Methods

2.2.1 Flash Point:

Determination of flash point is done ASTM D93 flash-point by pensky-martens closed cup tester, shown in fig. 1. A sample of the biodiesel is heated in a close vessel and ignited. When the sample burns, the temperature is recorded; the pensky-martens cup tester measures the lowest temperature at which application of the test flame causes the vapor above the sample to ignite. The biodiesel is placed in a cup in such quantity as to just touch the prescribed mark on the interior of the cup. The cover is then fitted onto the position on the cup and Bunsen burner is used to supply heat to the apparatus at a rate of about 5^{o}C per minute. During heating, the oil is constantly stirred. As the oil approaches its flashing, the injector burner is lighted and injected into the oil container after every 10 second intervals until a distinct flash is observed within the container. The temperature at which the flash occurred is then recorded, it is repeated two times and the average taken.

 DOI : 10.18231/2454-9150.2018.0694

Figure 1: Pensky - Martin Closed Cup Tester

2.2.2 Calorific Value:

Determination of calorific value was done by bomb calorimeter A sample was placed inside the crucible (1.00-1.5 gm) with attached Nichrome wire deep inside the sample having both the ends attached with the bomb. After sealing the vessel, the bomb was pressurized with oxygen upto 20 atm. The bomb is placed inside the water bath of 2000 ml of water taken in vessel. The temperature reading of the water bath was set to zero and the external spark source was given to ignite the sample. The rise in the water bath temperature was noted down.

Figure 2: Bomb Calorimeter

Calculation for calorific value for biodiesel blend

$$W \times \Delta T = H \times M ---------- (1)$$

W = calorific constant, cal/^{0}C

ΔT = Temperature rise, ^{0}C

H = Calorific value, cal/gm

M= weight of sample, gm

2.2.3 Property Prediction Correlations [10]:

There are number of correlations were utilized for prediction of property for the blend of biodiesel. For the prediction of mixture properties for the biodiesel blend different correlations can be used are listed as follows:

Kay:

$$n_m = v_1 n_1 + v_2 n_2 ------------ (2)$$

Newton:

$$n_m^2 - 1 = \sum_{i=1}^{n} \{vi(n_i^2 - 1)\} ---------- (3)$$

Eykman:

$$\frac{n_m^2 - 1}{n_m^2 + 0.4} = \sum_{i=1}^{n} \left\{vi\left(\frac{n_i^2 - 1}{n_i^2 + 0.4}\right)\right\} -------- (4)$$

Dale-Gladstone:

$$n_m - 1 = \sum_{i=1}^{n} \{vi(n_i - 1)\} ---------- (5)$$

Lorentz-Lorenz:

$$\frac{n_m^2 - 1}{n_m^2 + 2} = \sum_{i=1}^{n} \left\{vi\left(\frac{n_i^2 - 1}{n_i^2 + 2}\right)\right\} ---------- (6)$$

Here,

n_m is property of blend mixture,

n_i is property of pure component i,

v_i is volume fraction of component i.

The accuracy of predictive models was estimated with Root Mean Square Prediction Difference (RMSPD).

$$RMSPD = 100 * \sqrt{\frac{1}{n} * \sum_{i=1}^{n} \left[\frac{Y_{Cal,i} - Y_{exp,i}}{Y_{exp,i}}\right]^2} ----(7)$$

Here,

Y_{Cal} And Y_{exp} are the calculated and experimental values respectively,

n is the no. of experimental data.

III. RESULT AND DISCUSSION

3.1 Flash Point:

The experimental values of flash point using ASTM D-93 method was determined for the change in the blend ratio for the different biodiesel and petro-diesel blend samples. The values of Flash Point for various biodiesel volume fractions has been tabulated in Table No.1.

Table 1: Experimental Values of Flash Point and Calorific Values for Biodiesel Blends

Volume Fraction	Flash Point (◦C)	Calorific Value (KJ/Kg)
0	74	43,605
0.05	76	43,213
0.1	78	42,427
0.15	80	41,903
0.2	81	41,306
0.25	82	40,848
0.3	83	40,208
0.35	84	40,047
0.4	86	39,673
0.45	87	39,556
0.5	87	39,053
0.55	89	38,656
0.6	89	38,623
0.65	90	38,273
0.7	92	38,040
0.75	93	37,831
0.8	94	37,573
0.85	95	37,435
0.9	97	37,477
0.95	99	37,415
1	103	37,124

 DOI : 10.18231/2454-9150.2018.0694

It is observed that the flash point of blend is increasing with the increase in the biodiesel percentage. It indicates that the fuel with higher biodiesel fraction is safe in transportation and storage. The biodiesel blend has the higher flash point than the required as per the standards for the fuel.

The correlation for Flash point of biodiesel blend is:

$$F.P. = 40.35 \times v^3 - 58.09 \times v^2 + 45.83 \times v + 73.9 \quad (8)$$

Here,
v = Volume Fraction of biodiesel in blend.
The accuracy of the proposed equation has been compared with the other property prediction correlation. The comparative study is shown in Table No. 2.

Table 2: RMSPD values for different correlations for Flash Point and Calorific Value

Correlation	RMSPD (%) Flash Point	RMSPD (%) Calorific Value
Kay	2.07	2.43
Newton	2.60	2.66
Eykman	2.54	1.73
Dale-Gadestone	2.07	2.43
Lorentz-Lorenz	2.54	1.73
Proposed Eq.	0.52	0.298

3.2 Calorific value:

The experimental values of calorific values were determined using Bomb Calorimeter. The experimental data are shown in Table No. 1.

The experimental values indicate that the calorific values of biodiesel blend are decreasing with increase in biodiesel fraction in blend. These suggest that the quantity of biodiesel required for generation of same amount of energy is higher as compare to petro-diesel. That also suggests that the higher pumping of fuel is required in IC engine.

The correlation for the calorific values of Jatropha based biodiesel and petro diesel blend is:

$$C.V = 5638 \times v^2 - 11934 \times v + 43578 - - - (9)$$

Here,
C.V = Calorific Value of blend, KJ/kg,
v = Volume Fraction of Biodiesel in Blend.
The accuracy of the proposed equation has been compared with the other property prediction correlation. The comparative study is shown in Table No. 2.

IV. CONCLUSION

The present study directly correlates the thermal efficiency and blend fraction of fuels. It is clearly indicated that the Flash point of the blend increases with increase in biodiesel fraction in the blend of biodiesel and petro-diesel. This implies biodiesel are thermally more stable and safer to use because of higher fire and flash point. Next, calorific value of vegetable oil based biodiesel decreases with increase in the biodiesel fraction in blend. This indicates need of biodiesel blend with the petrol or diesel for better performances. The correlations found are applicable for the any volume fraction of biodiesel in blend. Also, it gives high accuracy for the both the properties.

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 DOI : 10.18231/2454-9150.2018.0694