Development of Empirical Models for Predicting Cold Flow Properties of Biodiesel Blends

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***Abstract*- Biofuel is promising alternative to maintain both human health and environment quality better by reducing harmful emission from biofuel runs diesel engines. Though biodiesel satisfy the ASTM and EN limits, it cannot be used alone in diesel engine due to its high kinematic viscosity and density and also lower oxidation stability and heating value; high viscosity and density and poor cold-flow properties compared to mineral diesel fuel. To improve those properties, it is blended with diesel. The blending of biodiesel with mineral diesel is the most common method for overcoming low temperature flow problems in biodiesel and improving their properties due to their similar characteristics. The properties of biodiesel blends is based on the composition of blend, and the estimation of various properties of biodiesel blends is required for process design and for combustion characteristics in diesel engine. In the present work empirical models have been developed for the prediction of cloud point of three types of biodiesel (Jatropha, Karanja and Palm) and its blend with diesel.**

***Keywords*- blending, biodiesel, cold flow property, pour point, models**

I. INTRODUCTION

Energy is a basic requirement for human existence [1]. Serious environmental issues, dwindling reserves of crude oil, oscillating petroleum fuel prices, and the overconsumption of liquid fuels, especially for the transportation purposes, have made today's necessity to find some viable substitute sources of alternate "green" energy which are sustainable, environmentally tolerable, economically competitive, and easily available. Biodiesel comes as a natural and optimum alternative to regular diesel in remidifying of the problems to some extent. Biodiesel is one of the foremost Green fuels which are consistently gaining attention as a viable substitute for petroleum diesel in a near future due to its remarkable characteristics [2].

According to the American Society for Testing and Materials (ASTM), biodiesel ("bio" from life in Greek and "diesel" from Dr. Rudolf Diesel, German engineer, who invented the diesel engine which is able to run on a host of fuels including coal dust suspended in water, heavy mineral oil, and vegetable oils) is defined as mono-alkyl esters derived from lipid feed stocks, such as vegetable oils or animal fats. Biodiesel, ensuring a flashpoint of 423 K, is a non-flammable and non-explosive fuel in contrast to petroleum diesel having flashpoint of 337 K.

But limitations occur in commercialization of biodiesel as an alternate fuel owing to its cold temperature properties which get significantly degraded. Crystallization of the saturated FAME components of biodiesel during cold seasons caused fuel starvation and operability problems as solidified materials clog fuel lines and filters [3]. This makes blending of biodiesel with conventional diesel not only inevitable but also attractive area of research for academicians and industrialists alike. Biodiesel is completely miscible with diesel and the blending in any proportion is possible in order to improve the fuel qualities. The need for development of empirical models to predict properties of biodiesel like pour point are being discussed in literature. They provide an accurate and reliable way to exemplify the data which are obtained experimentally. They also help in avoiding repetitive experimentation saving valuable time whilst giving accurate results.

II. BIODIESEL BLENDING AND VARIOUS BIODIESEL BLENDS

A post-production strategy which could potentially enhance the economic viability of the whole production cycle through value addition to biodiesel or its blends is to improve biodiesel properties, engine performance, and exhaust emission characteristics. As biodiesel is completely miscible to diesel, biodiesel and diesel blend are prepared using a beaker glass on a volume basis and the mixture is to be agitated with a shaker for about 15–30 min at ambient temperature. The volume fractions of the blends that are used in all experimental work have to be in the following proportion 5% (B5-5%biodiesel and 95% diesel), 10%, 15%, 20%. Also 100% pure biodiesel & 100% pure diesel can be used for critical property estimation and getting the range for experimental work. Violent shaking must be done to ensure complete homogeneity of oils in the beaker.

Blends of biodiesel and conventional hydrocarbon-based diesel are produced by mixing biodiesel and petroleum diesel in suitable proportions under appropriate conditions. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix:

- 100% biodiesel is referred to as B100, while
- 20% biodiesel, 80% petrodiesel is labeled B20
- 5% biodiesel, 95% petrodiesel is labeled B5
- 2% biodiesel, 98% petrodiesel is labeled B2

Low-Level Blends

They are B5 & B2 which are ASTM approved for safe operation in any compression-ignition engine designed to be operated on petroleum diesel. This can include light-duty and heavy-duty diesel cars and trucks, tractors, boats, and electrical generators.

B5- blend is 5% biodiesel and 95% petroleum based diesel. It is one of the most common blends associated with biodiesel because of the use of a B5 blend in state or municipal mandates

B2- is a blend of 2% biodiesel, 98% petro-diesel. It is one of the most common blends associated with biodiesel.

High Level Blends

B100 and other high-level biodiesel blends are less common than B20 and lower blends due to a lack of regulatory incentives and pricing. B100 can be used in some engines built since 1994 with biodiesel-compatible material for certain parts, such as hoses and gaskets.

B100- is 100% biodiesel. It has a solvent effect and it can clean a vehicle's fuel system and release deposits accumulated from previous petroleum diesel use. The release of these deposits may initially clog filters and require filter replacement. When using high-level blends, a number of issues should be considered. The higher the percentage of biodiesel above 20%, the lower the energy content per gallon. High-level biodiesel blends can also impact engine warranties, gel in cold temperatures, and may present unique storage issues. B100 use could also increase nitrogen oxides emissions, although it greatly reduces other toxic emissions. It may require special handling and equipment modifications [4].

B20- (20% biodiesel, 80% petroleum diesel) is the most common biodiesel blend. B20 is popular because it represents a good balance of cost, emissions, cold-weather performance, materials compatibility, and ability to act as a solvent. Using B20 provides substantial benefits and avoids many of the cold-weather performance and material compatibility concerns associated with B100. B20 and lower-level blends generally do not require engine modifications. Engines operating on B20 have similar fuel consumption, horsepower, and torque to engines running on petroleum diesel [5].

III. COLD FLOW PROPERTIES OF BIODIESEL

Crystallization of the saturated fatty acid during winters causes fuel starvation and operability problems as solidified material clogs to fuel lines and filters. With decreasing temperature more solid is formed and material approaches the pour point which is the lowest temperature at which it will cease to flow. It has been well established that the presence of higher amount of saturated components increases the cloud point and pour point of biodiesel utilization of additives that enhance the impact of crystal morphology and blending with a fuel like kerosene which causes freezing point depression [6].

The cold flow properties of biodiesel become very important for lower temperature applications of biodiesel. As discussed above, the cold flow properties of biodiesel are higher than that of conventional diesel. This provides a constraint for the use of biodiesel as a fuel like diesel. This is one of the main reasons why B20 is regarded as the most optimum fuel blend for commercial applications. Table below enlists the various models for cold flow properties of biodiesel discussed in literature. They are complicated to use as they need specific data for each sample. We attempted on simplifying these models for our system.

TABLE I MODELS FOR COLD FLOW PROPERTIES

Property	**Name of Model**	**Model Equation**	**Requirements for Models**	**% ARD**
Cloud Point	Yung et. al.	$CP=18.134N_C-0.790U_{FAME}$	N_C = weighted avg. no. of carbon atoms U_{FAME} = Composition of FAMEs in biodiesel	1.10
	Sarin et. al.	$CP=0.526P_{FAME}-4.992$	P_{FAME} = Content of Palmitic acid methyl ester	1.05
Pour Point	Yung et. al.	$PP=18.88N_C-1.000U_{FAME}$	N_C = weighted avg. no. of carbon atoms U_{FAME} = Composition of FAMEs in biodiesel	1.43
	Sarin et. al.	$PP=0.571P_{FAME}-12.24$	P_{FAME} = Content of Palmitic acid methyl ester	1.56

IV. TEST FUEL PREPARATION

Three Bio-diesels namely Palm, Jatropha & Karanja wee used. Jatropha Bio-Diesel was procured from CMSCRI while others were locally procured. Blends were made of B5, B10, B15, B20 & B100 respectively. The biodiesel diesel blends are prepared precisely in beaker on a volume basis and agitation/splash basis of about 2000 rpm for 15 min to ensure homogeneity. The blends were made 30 minutes prior to experiments being performed to minimize chances of error.

V. POUR POINT SETUP

The apparatus used for cloud point and pour point measurement is Digital cloud point and pour point apparatus with refrigerated compartments. The lowest temperature upto which cooling can take place by this instrument is -30°C. Thermocouple was used for temperature measurement. The cloud point is recorded as the haziness (cloud-like appearance) is visible at the bottom of the sample holder; which was not possible to see with naked eyes in this setup. Consequently pour point was obtained as the last point at which the fuel sample ceases to flow.

VI. EXPERIMENTAL RESULTS AND DISCUSSION

The result for Pure Bio and Petro diesel B100 are shown followed by Pour Point values for blends are shown. The blends are B5, B10, B15 & B20 respectively.

TABLE: - 2 POUR POINT VALUES FOR B100

Sample	Pour Point [°C]
Diesel	-17.25
Palm Oil	0.75
Jatropha Oil	-5.225
Karanja Oil	2.4

TABLE: - 3 POUR POINT VALUES FOR BXX

Biodiesel Blend	B5 [°C]	B10 [°C]	B15 [°C]	B20 [°C]
Palm Oil	-12.8	-13.0	-16.5	-14.9
Jatropha Oil	-15	-14.7	-14.1	-13.8
Karanja Oil	-14.8	-12.5	-12.2	-12.2

The graphical representation of these values is shown in figures below for pure and blends with curves fitted to optimal values in blends.

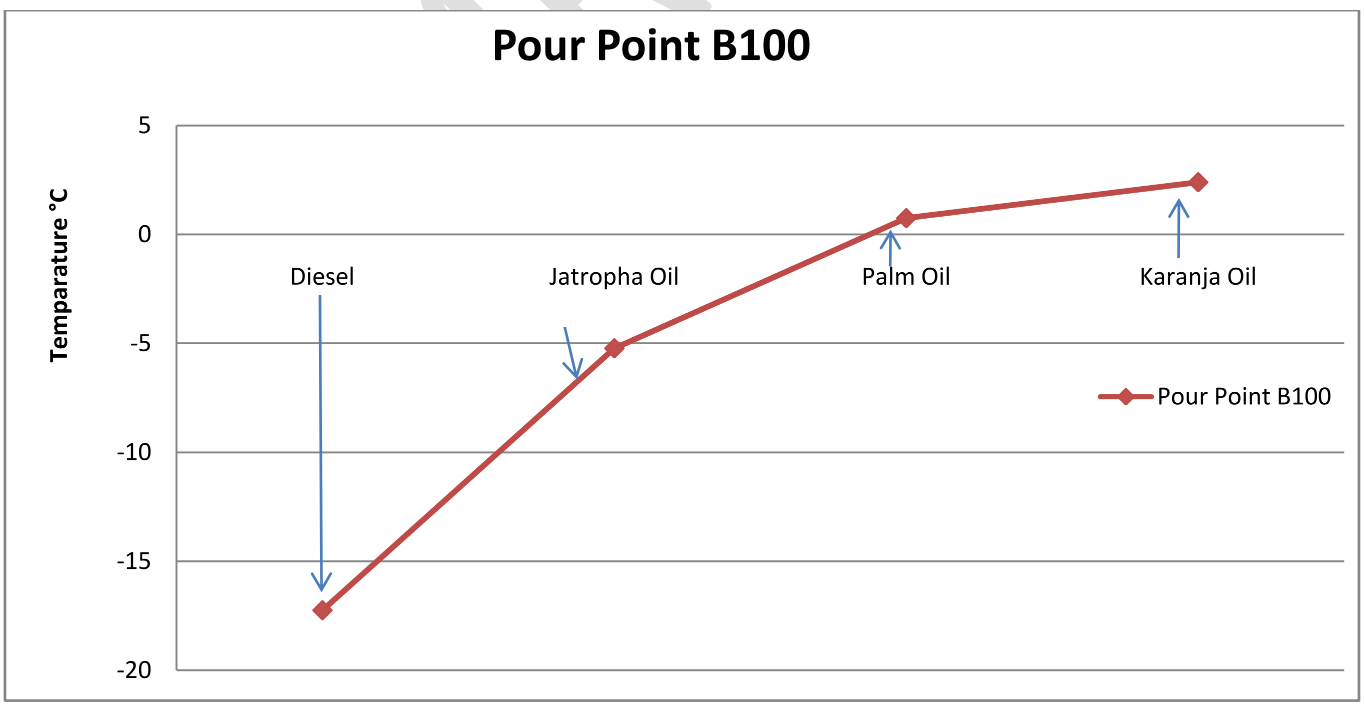

Figure 1 Pure Sample

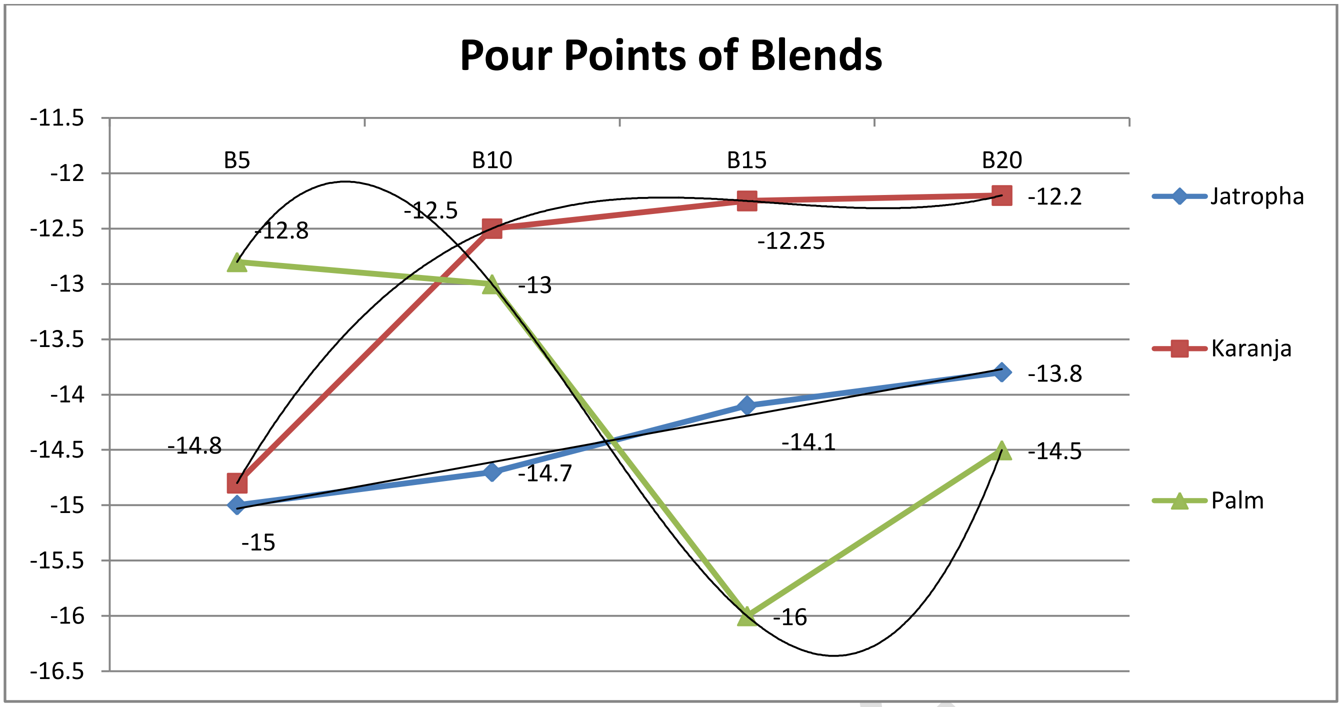

Figure: 2- Blend Pour Point Result

As shown qualitatively in Figure 1, the pour point comes in ascending order for Jatropha, Palm and Karanja. This data is useful when testing of blend is done as the range approximation and behaviour can be assumed.

Jatropha Blend showed the most linear relationship. This might be due to the fact that its density and viscosity is similar to pure diesel. However the range of temperature difference is very small (-1.2 °C) only. Karanja Blend showed a rise in the pour point value from B5 to B10 and after that the results were almost linear. Due to its high viscosity the blend might show this result.

The results of Palm Blend were very peculiar as opposing the conventional norms, a dip was observed instead of rise at higher blend values. Enough time was not available to study this result but a theory is developed that "Due to its high density even after mixing of the blend, separation may have occurred during the experiment and this may have resulted in such characteristics". In such cases additives are highly recommended.

At completion of experiments and obtaining graphs for each system curve fitting for each system was done and equation were developed for all systems as shown below.

TABLE: - 4 EMPIRICAL EQUATION FOR BLENDS

Blend	Equation
Karanja	$y = 0.308x^3 - 2.875x^2 + 8.766x – 21$
Jatropha	$y = 0.42x - 15.45$
Plam	$y = 1.216x^3 - 8.7x^2 + 17.38x - 22.7$

Where y is the cloud point for that particular reading and x is volumetric proportion of biodiesel in diesel blend.

V1. CONCLUSION

Experiments were performed which were helpful in determining major cold flow property for bio-diesel blends. Also models for pour point, with respect to volume fraction were prepared. Biodiesel increment did not affect cold flow properties at low blend levels (B5 and below); but as Bxx Increased the value changed. Other important conclusions were that variances in cold flow property data at low blend levels (B1 to B2) were generally statistically equivalent regardless of the feedstock. Application of least-squares statistical regression to PP data revealed distinct mathematical relationships between cold flow properties and blend ratio. Specifically, different bio-diesel showed different relationships and they provided the highest R2 values when fitted to their specific equations. In summary, these results should be useful to biodiesel producers and blenders who are concerned with cold flow property issues, as this study demonstrated that in most cases feedstock selection for biodiesel fuel had minimal impact on cold flow properties at low blend levels permitted by ASTM D975. PP of the blended biodiesels had a close relationship with the FAME composition. Therefore, to improve the poor biodiesel low temperature flow properties, blending of biodiesels over two is a simple but effective method and also it can minimize the use of edible oils. With the help of correlations between biodiesel low temperature flow properties and the FAME compositions, the low temperature flow properties of biodiesels produced from new resources can be easily estimated.

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