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INVESTIGATION OF OPTIMUM BLEND RATIO OF JATROPHA, PALM, COCONUT AND WASTE COOKING OIL BASED BIODIESEL TO IMPROVE FUEL PROPERTIES

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***Abstract**-. Fossil fuel is depleting due to increase in usage and the world is facing energy crises. In order to get out of such plight situations, scientists are looking into alternative ways to produce energy at low cost and eco-friendly. One such solution would be biodiesel. But biodiesel has some limitations to use as fuel because of poor fuel properties. This experiment was conducted using jatropha, palm, coconut and waste cooking oil biodiesel to improve fuel properties by blending. Among these four types of biodiesel, taking two or three at a time, total ten types of optimum blends were obtained. MATLAB optimization tool was used to find out the optimum blend ratio and the MATLAB code was developed considering linear relationship among the fuel properties in blends. The resultant optimum blend ratio and the linear equation of the MATLAB code were used to predict the fuel properties value and compared with the experimental fuel properties values of the optimum blends. For ten types of blends, ten specific blend ratios were obtained which had better overall fuel properties than individual biodiesel present in the blends.*

Keywords: Biodiesel, Fuel properties, Optimization, Optimum blend

1. INTRODUCTION

The world energy crisis due to depletion of fossil fuel and increasing environmental concerns leading scientists to look for an alternative source of energy which is eco-friendly as well. In order to solve this problem, many countries over the world have started lots of research [1, 2]. One such solution would be biodiesel as it is nontoxic and biodegradable [3-6]. Use of biodiesel minimizes greenhouse gases emission because of close carbon cycle [4, 7, 8].

Use of biodiesel sometimes extends engine component life [7, 9]. It can be used in existing diesel engine without any modification [10]. But sometimes little modification is recommended because biodiesels have some different fuel properties compare to ordinary diesel. There are some important key fuel properties which should be characterized before using in a diesel engine. These properties include density, kinematic viscosity, flash point, calorific value etc. Fuel flow, spray and atomization characteristic are directly governed by the density and kinetic viscosity of the fuel. Combustion is also influenced by it [11-13]. High viscosity which causes poor atomization, engine deposits and increases fuel pump energy consumption [14 and also causes problem in cold countries by freezing. Transesterification of biofuel improves this fuel property [15]. Higher flash point makes fuel safer for handling and storage and prevent unexpected ignition of fuel during combustion. Higher calorific value for fuel is desired because it facilitates the heat release during combustion and improves engine performance at lower fuel consumption.

Many researchers conducted their experiment to improve biodiesel fuel properties blending with petroleum diesel [14, 16, 17]. In this paper, biodiesel fuel properties have been improved by blending two or three pure biodiesel. Here four different biodiesels i.e. jatropha, palm, coconut and waste cooking oil biodiesel have been used. Jatropha and waste cooking oil have been chose as they come from non-edible sources and increase use of these two biodiesel will not affect our food chain. In addition, the reason of choosing palm and coconut biodiesel is their good fuel properties. MATLAB optimization tool has been used to find out the optimum blend ratio and the experimental optimum blended fuel properties have been compared with the theoretical fuel property values.

2. BLENDING METHOD

Experiments were conducted using two or three biodiesel blends of jatropha, palm, coconut and waste cooking oil based biodiesel. Many researchers found from their experiment that most of the important fuel properties like density, kinematic viscosity, oxidation stability, flash point, calorific value and cetane number vary linearly in case of multiple biodiesel blends [14, 16-19].To find out the optimum blending ratio, here the linear relationship had been considered and MATLAB optimization tool had been used.

To find out the optimum blend ratio, first some boundary conditions were considered. The upper and lower limit for a specific fuel property was considered according to the highest and lowest value of that property of the individual fuel, present in the blend and also the ASTM standard. Again for those properties for which lower value is desired (i.e. viscosity, density), the median value of that specific fuel property was considered as the height limit. For example, in case of jatropha-palm-coconut blend, jatropha got the lowest induction value and the coconut got the highest value among them and according to ASTM standard, induction value should be at least 3 hours. So here boundary condition was set higher than 3 hours. Besides, in case of viscosity jatropha got the highest and coconut got the lowest value. As palm got the median value among the three, so palm viscosity value was considered as the maximum limit for the final blend.

3. EXPERIMENTAL PROCEDURE

Engine performance and emission is directly affected by the physiochemical properties of the fuel like density, viscosity, flash point, fire point, oxidation stability, cetane number, iodine value, acid value etc. These properties indicate the quality of a fuel. Among these properties, most of the researchers concentrated their mind to density, kinematic viscosity, oxidation stability, flash point, calorific value and cetane number to determine the quality of fuel [20-25]. There are different types of standard like ASTM, BS, ISO, etc. to define the fuel properties. These standards have defined the range of each of the fuel properties. Among these standards ASTM is the most widely followed standard. To meet the standard engine performance and emission, the value of the fuel properties must be in the range.

The individual fuel properties of JB, PB, CB and WB were tested using different fuel properties measuring apparatus listed in Table 1 and the resultant fuel property values are represented in Table 2. MATLAB code considering linear relationship among the fuel properties in the blends was written to find out the optimum blend ratio for two or three fuel blends. The boundary conditions, considered for the MATLAB optimization are mentioned in Table 3 and also the resultant blend ratios. These boundary limits for each of the properties were decided according to maximum and minimum value of the corresponding fuel property of the individual fuel involved in the blend and also the ASTM standard. Then using the optimum blend ratio and the linear equations the theoretical fuel properties value for the blends were determined. Finally the blends were prepared according to the optimum blend ratio and the fuel properties of the blends were tested in the lab (Table 4).

Table 1: Apparatus for fuel property test

Properties	Apparatus
Density	Stabinger Viscometer SVM 3000 Manufacturer: Anton Paar
Kinematic Viscosity	
Induction Time	873 Biodiesel Rancimat Manufacturer: Metrohm
Flash Point	Pensky-Martens flash point-automatic NPM 440 Manufacturer: Normalab, France
Calorific value	Semi auto bomb calorimeter Model: 6100EF Manufacturer: Parr, USA

Table 1: Experimentally investigated individual fuel properties

Properties	Standard and limit	Jatropha Biodiesel	Coconut Biodiesel	Palm Biodiesel	Waste Cooking Oil Biodiesel	Diesel
Density (g/cm^3)	-	0.8650	0.8594	0.8592	0.8632	0.8331
Kinematic Viscosity at 40^o C (cSt)	ASTM-D445 (1.9-6)	4.6385	4.6281	4.6175	4.962	3.556
Induction time (hrs)	ASTM (3hrs min)	2.08	5.12	3.24	0.04	-
Flash Point (^oC)	ASTM-D93 (130^oC min)	202.5	136.5	188.5	170.5	77.5
Calorific Value (kJ/g)	-	39.839	36.9851	39.907	38.8755	44.664
Cetane Number	ASTM-D613 (47 min)	51	60	55	49	47

Table 2: Boundary conditions and optimum blending ratio derived using Matlab

Blend content	Boundary Limit						Optimum BlendRatio (%)			
	Maximum Density (gm/cm^3)	Maximum Kinematic Viscosity at 40°C (cSt)	Minimum Induction time (hrs)	Minimum Flash Point (°C)	Minimum Calorific Value (kJ/g)	Minimum Cetane Number	JB	PB	CB	WB
B_{JP}	0.86	4.625	3	160	39.85	53	17.3	82.7	0	0
B_{JC}	0.86	4.635	3	160	38.0	55	38.5	0	61.5	0
B_{JW}	0.87	4.7	1.7	160	39.0	50	74.9	0	0	25.1
B_{PC}	0.86	4.628	3	160	39.5	55	0	52.4	47.6	0
B_{PW}	0.86	4.65	3	160	39.5	53	0	89.8	10.2	0
B_{CW}	0.86	4.75	3	150	37.5	53	0	0	57.4	42.6
B_{JPC}	0.86	4.625	3	160	38.5	55	10	74.1	15.9	0
B_{JPW}	0.86	4.7	2.5	160	39.0	53	10.6	62.1	0	27.3
B_{PCW}	0.86	4.75	3	160	38.5	53	0	33.3	30.2	36.5
B_{JCW}	0.86	4.75	3	160	38.5	53	30	0	40	30

Table 3: Experimental blended fuel properties

Fuel	Density (gm/cm^3)	Kinematic Viscosity at 40°C (cSt)	Induction time (hrs)	Flash Point (°C)	Calorific Value (kJ/g)	Cetane Number
B_{JP}	0.8607	4.6337	3.3	186.5	39.8763	54
B_{JC}	0.8637	4.6352	3.72	170.5	38.3214	56
B_{JW}	0.8648	4.6537	1.7	187.5	39.836	51
B_{PC}	0.8597	4.6137	4.04	172.5	39.0110	58
B_{PW}	0.8537	4.6237	2.8	182.5	38.886	53
B_{CW}	0.8598	4.7589	3.52	145.5	37.676	55
B_{JPC}	0.8599	4.6385	3.53	182.5	38.8398	56
B_{JPW}	0.8613	4.7045	2.7	194.5	39.876	53
B_{PCW}	0.8625	4.7687	3.14	160.5	38.735	53
B_{JCW}	0.8638	4.7248	3.21	170.5	39.176	53

4. RESULTS AND DISCUSSION

The experimental fuel properties of JB, CB, PB, WB and OD (Table 2) showed that the density of all biodiesels were very close to each other and about 3-3.5% higher than petroleum diesel. The kinematic viscosity of all biodiesels were also very close to each other except WB which got the highest and about 6.5% higher than other biodiesels. A large variation was observed in case of induction time. JB and WB got very poor induction time and lower than ASTM standard (3 hours). PB got an induction time very close to the ASTM standard and CB got the highest (5.12 hours). The flash point of all the biodiesels were high enough except the CB which was very close to the minimum ASTM limit (130°C). The calorific value (CV) of the biodiesels was on average 11% lower than OD. CB got the lowest CV (36.98 kJ/g). The cetane number (CN) of the biodiesels were higher than OD and higher CN value is desired for better engine performance.

To find out the optimum blend ratio using MATLAB, boundary conditions were much more important. The boundary limit for each of the properties was decided according to maximum and minimum value of the corresponding fuel property of the individual fuel involved in the blend and also the ASTM standard. But in case of B_{JW} and B_{JPW}, the boundary conditions for induction time were lower than ASTM standard because individual fuel involved in the blend initially got an induction time very close to or lower than the minimum standard value.

The comparison of the theoretical and experimental blended fuel properties showed that the deviations of density, kinematic viscosity, CV and CN were lower than 2%. But the deviations sometime exceeded the limit of 5% for induction time and flash point.

The comparison of Table 2 and Table 4 can easily show the improvement of properties. Among the four biodiesel, JB got the highest density value but B_{JP}, B_{JC}, B_{JW}, B_{JPC}, B_{JPW} and B_{JCW} got a density lower than pure JB. Again, WB got the lowest induction time but B_{JW}, B_{PW}, B_{CW}, B_{JPW}, B_{PCW} and B_{JCW} had induction time higher than WB. However, induction time of B_{JW}, B_{PW} and B_{JPW} were lower than ASTM standard because the individual induction time of the biodiesel present in the blends was very close to or lower than the standard. This phenomena indicated that the blend of two or more biodiesel could improve fuel properties. Besides, induction time of B_{PCW} and B_{JCW} met the ASTM standard and indicated that it was easy to improve fuel property blending three or more biodiesel rather than two.

Figure 1 shows the variation between the theoretical (obtained using the optimum blend ration and the linear equations used in MATLAB) and experimental (obtained from lab test) fuel properties. In case of induction time and the flash point, the variation was relatively high (maximum 8.5%) because these two properties were affected by chemical composition of fuel and molecular structure. For the other fuel properties, the variation was very low (less than 3%) and it validated the linear relationship of the fuel properties for blends that was considered to find out the optimum blend ratio using MATLAB.

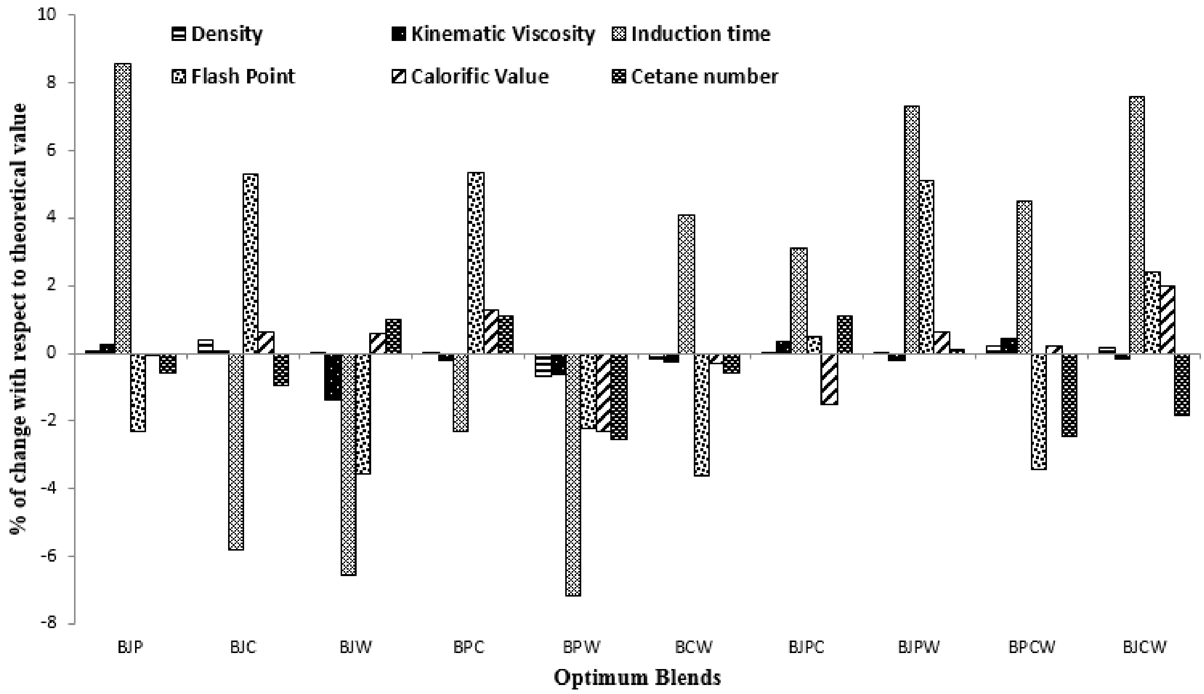

Fig. 1: Percentage (%) of variation between theoretical and experimental blended fuel properties

5. CONCLUSION

Density, viscosity, heating value, flash point, cetane number, etc. are the most important fuel properties which indicate the quality of a fuel. Engine performance and emission are directly related to these fuel properties. There are different types of standard like ASTM, BS, ISO, EN etc. to define the fuel properties. These standards have defined the range of each of the fuel properties. Among these standards ASTM is the most widely followed standard. To meet the standard engine performance and emission, the value of the fuel properties must be in the range. In this regard study of fuel properties are the most important part to use any liquid as fuel. Now-a-days, blending is being widely used to improve biodiesel fuel properties.

In this study our main objective was to improve fuel properties and the following conclusions are drawn as a summary of the experiment:

- Fuel properties can be improved by blending two or more biodiesels.
- There is an optimum blend ratio to improve fuel properties.
- The properties of fuel vary linearly in case of multi fuel blend.
- Blend of more biodiesel can easily improve fuel property rather than two.

6. ACKOWLEDGEMENT

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8. NOMENCLATURE

Symbol	Meaning
JB	Jatropha biodiesel
PB	Palm biodiesel
CB	Coconut biodiesel
WB	Waste cooking oil biodiesel
OD	Ordinary diesel
B_{JP}	Jatropha biodiesel and palm biodiesel blend
B_{JC}	Jatropha biodiesel and coconut biodiesel blend
B_{JW}	Jatropha biodiesel and waste cooking oil biodiesel blend
B_{PC}	Palm biodiesel and coconut biodiesel blend
B_{PW}	Palm biodiesel and waste cooking oil biodiesel blend
B_{CW}	Coconut biodiesel and waste cooking oil biodiesel blend
B_{JPC}	Jatropha biodiesel, palm biodiesel and coconut biodiesel blend
B_{JPW}	Jatropha biodiesel, palm biodiesel and waste cooking oil biodiesel blend
B_{PCW}	Palm biodiesel, coconut biodiesel and waste cooking oil biodiesel blend
B_{JCW}	Jatropha biodiesel, coconut biodiesel and waste cooking oil biodiesel blend