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Analytical Study for Palm-Jatropha Biodiesel Spray Characteristics

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Abstract *- ANALYTICAL STUDY FOR PALM-JATROPHA BIODIESEL SPRAY CHARACTERISTICS. This paper presents analytical evaluation of biodiesel blends with diesel fuels using indirect injection spray injector. The biodiesel under study is a 60:40 blend of used frying oil (from palm) and jatropha oil. The reason for selecting this composition is the best trade off for obtaining oxidation stability and saturation properties. Used frying oil is selected for economical reason. The physico-chemical properties, i.e. density, surface tension, and viscosity, are evaluated for B100, B5, B10, B20, and B30. Such data are required for input parameters of a spray modelling which is under preparation. The above properties can be used to predict the spray characteristics under typical injection pressure and air density. In this study, only the Sauter mean diameter (SMD) is evaluted using semi-empirical formulae from other study. It is found that the SMD for the above biodiesel blend is 24.6 μm, compared with 20.4 μm for pure diesel fuel. The SMD for other compositions are also evaluated up to B30; in which it is found that the SMD is 21.6 μm. The effect of injection pressure is also studied.*

Keywords: *Palm, Jatropha, Biodiesel, Spray, Sauter mean diameter.*

Abstraks – STUDI ANALITIK TERHADAP KARAKTERISTIK *SPRAY* BIODIESEL SAWIT-JARAK. Pada Makalah ini disampaikan analisa terhadap karakteristik campuran biodiesel-minyak solar pada nosel injeksi tak langsung. Campuran yang sedang diteliti adalah minyak jelantah dari sawit dan minyak jarak dengan komposisi 60:40. Alasan pemilihan komposisi tersebut adalah berdasarkan kompromi yang terbaik antara stabilitas oksidasi dan sifat jenuhnya. Minyak jelantah dipilih karena alasan ekonomis. Sifat-sifat fisika kimia, yaitu densitas, tegangan permukaan, dan viskositas, dihitung untuk bahan bakar B100 (minyak solar murni), B5, B10, B20, dan B30. Data tersebut diperlukan sebagai input untuk modeling spray yang tengah dalam persiapan. Sifat-sifat diatas dapat digunakan untuk memprediksi karakteristik spray pada kondisi tekanan injeksi dan densitas udata yang lazim terjadi pada mesin. Pada penelitian ini hanya parameter diameter rata-rata Sauter (SMD) yang dihitung menggunakan rumus semi empris dari studi lain.*Hasilnya menunjukkan bahwa SMD untuk campuran biodiesel diatas adalah 24.6 μm, dibandingkan dengan 20.4 μm untuk minyak solar murni. SMD untuk komposisi lain juga dihitung hingga B30, dimana SMDnya diperoleh sebesar 21.6 μm. Efek dari tekanan injeksi juga dipelajari.*

Kata Kunci: Sawit, Jarak, Biodiesel, spray, diameter rata-rata Sauter

I. INTRODUCTION

Biodiesel is an environment friendly liquid fuel similar to petro-diesel in combustion properties. Increasing environmental concern, diminishing petroleum reserves and as a way to agriculture-based economy, are the driving forces to promote biodiesel as an alternate renewable transportation fuel. Biodiesel derived from vegetable oil and animal fats is being used in other countries to reduce air pollution, to reduce dependence on fossil fuel, whose resources are limited and localized to some specific regions.

Indonesia has allowed biodesel blend as much as 10% to be commercially purchased in public gas stations, especially in the Jakarta area.

In this study biodiesel blend of used frying oil (from palm oil) and jatropha is investigated. The former has been throughly studied due to its abundant availability, low cost, and good characteristics (oxidation stability and high cetane number) after treatment. Whereas the latter is used since it is non-edible oil and has better flow properties than those of palm oil at low temperatures, i.e. pour point, cloud point, and cold flow plugging point. However, since the oxidation stability of jatropha is lower than palm oil, its fraction in the blend should be limited. Sarin [1] has showed that the jatropha's fraction in the mixture with palm oil is limited to 40% maximum in order to keep the oxidation stability within International standards (e.g. European standard requires minimum of six hours).

There has been significant work on biodiesel stability [2]. As biodiesel chemically is an ester molecule there is every possibility that in the presence of air or oxygen it will be hydrolyzed to alcohol and acid. Presence of alcohol will lead to reduction in flash point and presence of acid will increase total acid number. All these make methyl ester relatively unstable on storage and cause damage to engine parts. This is why the oxidation stability is an important criterion for biodiesel. Stability of biodiesel is inferior compared to diesel fuel and therefore doping of biodiesel in diesel fuel will affect the stability of fuel significantly [3]. The poor stability of biodiesel is also because of the double bonds in the fatty acids, which may lead to gum formation. In either of the cases the product will become off spec. Therefore, it was considered to include a limit for oxidation stability in the

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existing quality standard for biodiesel. Almost in all biodiesel fuel significant amounts of esters of oleic, linoleic or linolenic acids are present and the trend of increasing stability was linolenic < linoleic < oleic. These esters undergo auto-oxidation with different rates depending upon the number and position of the double bonds and results in formation of a series of by-products, like acids, esters, aldehydes, ketones, lactones, etc.

II. THEORY

The main objective of this study is to perform an analytical comparison of atomisation characteristics of various blends of biodiesel at 80°C, using a direct injection with the following blends: as the basis is 40%-60% jatropha-palm oil mix, and this is designated as B100. This is to be blended with diesel fuel at 5, 10, 20, and 30 % v/v fraction, designated as B5, B10, B20, and B30, respectively.

Physical properties of fatty acid methyl esther (FAME) at 80°C are given at Table 1. In this Table, the properties are broken down according to the composition of the acid constituents.

TABLE 1. *PHYSICAL PROPERTIES OF FAME AT 80°C [5]*

		ρ (g/ml)	ν (cSt)	γ (mN/m)
caprylic	C8/0	0.824	0.72	21.77
capric	c10/0	0.823	0.97	22.83
lauric	c12/0	0.822	1.31	23.61
myristic	c14/0	0.821	1.64	24.19
palmitic	c16/0	0.82	2.03	25.2
palmitoleic	c16/1			
stearic	c18/0	0.821	2.53	25.82
oleic	c18/1	0.838	2.19	27.13
linoleic	c18/2	0.845	1.92	27.49
linolenic	c18/3	0.86	1.81	28.23
arachidic	c20/0	-	-	-
behenic	c22/0	-	-	-
erucic	c22/1	0.84	3.22	28.39

The kinematic viscosity of mixtures, *?mix*, is predicted using equation:

$$\ln(\upsilon_{mix}) = \sum_i Y_i \ln \upsilon_i \qquad \text{(Eq. 1)}$$

Where Y_i is the mass fraction of the i^{th} liquid or constituent.

The surface tension of mixtures, *?mix*, is calculated as:

$$\gamma_{mix} = \left(\sum_i Y_i \gamma_i^{\,0.25} \right)^4 \qquad \text{(Eq. 2)}$$

whereas the density of the mixtures, *?mix*, are calculated as:

$$\rho_{mix} = \sum_i Y_i \rho_i \qquad \text{(Eq. 3)}$$

The droplet size correlation is derived from the above parameters, expressed in term of the Sauter mean diameter, D_S, and given as:

$$\overline{D}_S = 6156 \upsilon^{0.385} \gamma^{0.737} \rho^{0.737} \rho_a^{\,0.06} p^{-0.54} \qquad \text{(Eq. 4)}$$

Eq. (4) is valid within the following ranges: 0.81 x 10^{-6} < ?$_{mix}$ < 8.6 x 10^{-6} m^2/s, 20.4 < ?$_{mix}$ < 27.5 mN/m, 732 < ?$_{mix}$ < 847 kg/m3, and 78 < p < 200 bar.

Droplet Spray Model

One of the basic characteristics of an injection is the distribution of drop size. For an atomizer, the droplet diameter distribution is closely related to the nozzle state. A spray model is being prepared which uses a two-parameter Rosin-Rammler distribution, characterized by the most probable droplet size and a spread parameter. The most probable droplet size, is obtained from the Sauter mean diameter, $\overline{D}_S$. In order to run the model, therefore, reasonable prediction of the Sauter mean diameter is required. From the combustion point of view, smaller mean droplet diameter is preferred, since this would mean faster rate of evaporation, and hence, shorter ignition delay.

III. RESULTS

Mass fraction of typical Indonesian palm oil and jatropha oil is given at second and sixth column, respectively, of Table 2. If ones intend to implement the study from Indonesian resources, this is more indigenous data than those found from literatures [1] & [5],. From these, predicted physical properties were calculated using equations (1-3).

The Sauter mean diameters are then calculated from Eq. (4). Two different setting of injection pressures are calculated, 200 and 150 bars, as shown in Table 3 and Table 4.

IV. DISCUSSION

The last row of Table 3 shows the Sauter mean diameter of various blends of the biodiesel under study. As expected, the droplet size of the biodiesel is larger than those of diesel fuel. This implies that the atomisation characteristics of the biodiesel are not as good as diesel fuel. However, the magnitude of the differences is less than 4% for B10; and the differences are certainly negligible for B5. The combustion characteristics of the fuel is not only determined by the performance of atomisation, but also by the cetane number and oxygen content whereas the biodiesel blends have higher values than that that of diesel fuel.

The importance of sufficiently high injection pressure is apparent from comparing Table 3 and Table 4. In Table 4, the injection pressure is lowered from 200 bar to 150 bar (25% lower), which result in larger droplet diameter, about 20% larger.

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TABLE 4. *PHYSICAL PROPERTIES OF FAME AT 80°C [5]*

	Biodiesel from used frying oil				Jathropa			
	Y	ρ (g/ml)	ν (cSt)	γ (mN/m)	Y	ρ (g/ml)	ν (cSt)	γ (mN/m)
caprylic	0.96	0.00791	-0.00315	0.020737	0	0	0	0
capric	0	0	0	0	0	0	0	0
lauric	7.67	0.063047	0.020711	0.169071	0	0	0	0
myristic	3.37	0.027668	0.016671	0.074738	0	0	0	0
palmitic	59.73	0.489786	0.42291	1.338267	22.87	0.187534	0.161928	0.512408
palmitoleic	0	0		0	0	0		0
stearic	1.18	0.009688	0.010953	0.026599	0	0	0	0
oleic	24.14	0.202293	0.189234	0.550934	45.92	0.38481	0.359968	1.048007
linoleic	2.95	0.024928	0.019244	0.067548	31.21	0.263725	0.203591	0.71464
linolenic	0	0	0	0	0	0	0	0
arachidic	0	0		0	0	0		0
behenic	0	0		0	0	0		0
erucic	0	0	0	0	0	0	0	0
Aggregated			0.676569	2.247894			0.725486	2.275056

TABLE 3. *SAUTER MEAN DIAMETER FOR INJECTION PRESSURE OF 200 BAR*

Property	diesel	used frying (palm)	jathropa	B100	B5	B10	B20	B30
?(m^2/s)	1.400E-6	1.967E-6	2.066E-6	2.006E-6	1.425E-6	1.451E-6	1.504E-6	1.560E6
?(N/m)	0.0252	0.0255	0.0268	0.0260	0.0253	0.0253	0.0254	0.0255
? (kg/m^3)	801	825	836	830	802	804	807	810
? (kg/m^3)	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
p(bar)	200	200	200	200	200	200	200	200
D_s(μm)	20.41	24.00	25.58	24.63	20.60	20.79	21.19	21.59

TABLE 2. *SAUTER MEAN DIAMETER OF VARIOUS BIODIESEL BLENDS (INJECTION PRESSURE OF 150 BAR & OTHER PARAMETERS BEING KEPT CONSTANT)*

Property	diesel	used frying (palm)	jathropa	B100	B5	B10	B20	B30
?(m^2/s)	1.400E-6	1.967E-6	2.066E-6	2.006E-6	1.425E-6	1.451E-6	1.504E-6	1.560E6
?(N/m)	0.0252	0.0255	0.0268	0.0260	0.0253	0.0253	0.0254	0.0255
? (kg/m^3)	801	825	836	830	802	804	807	810
? (kg/m^3)	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
p(bar)	150	150	150	150	150	150	150	150
D_s(μm)	23.84	28.04	29.88	28.76	24.06	24.29	24.75	25.22

V. CONCLUSION

Prediction of Sauter mean diameter of various blends of biodisel have been obtained using semi-empirical formulae. The results seem reasonable. The effect of injection pressure is also logical. Thus, important data for input for spray modelling are thus ready.

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