INFLUENCE OF BIODIESEL FORMULATION AND BLENDING TO FUEL PROPERTIES

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
B5	5 Percent Biodiesel Blends
B10	10 Percent Biodiesel Blends
B20	20 Percent Biodiesel Blends
B100	Pure Biodiesel
DOEB	Department of Energy Business
EN	European Norm
FAME	Fatty Acid Methyl Ester
FFA	Free Fatty Acid
GB	Guobiao National
KOH	Potassium Hydroxide
MS	Malaysian Standard
RSOB	Rubber Seed Oil Biodiesel
SNI	Standard National Indonesia
TCVN	Vietnam National Standard
WCOB	Waste Cooking Oil Biodiesel

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ABSTRAK

Biodiesel adalah bahan pembakar alternatif untuk minyak diesel mineral yang dihasilkan oleh bahan – bahan yang diperbaharui seperti minyak sayur dan lemak haiwan. Minyak sayur menjanjikan sebagai langkah alternatif untuk minyak diesel kerana minyak sayur secara semulajadinya diperbaharui dan boleh dihasilkan oleh negara tempatan dan mesra alam. Dalam kajian ini membentangkan tentang sifat biodiesel mempengaruhi oleh formulasi dan percampuran. Dua jenis biodiesel daripada minyak biji getah dan sisa minyak masak akan diuji berdasarkan spesifikasi ASTM D6751 dan EN 14214 untuk nilai asid, FFA, kelikatan kinematik, takat beku, takat awan, ketumpatan and nilai kalori sama ada daripada biodiesel tulen atau dicampur dengan petrodiesel. Sepanjang kajian ini dijalankan, teknik percampuran menunjukkan cara alternatif untuk mengurangkan penggunaan petrodiesel untuk kegunaan pengangkutan. Biodiesel daripada sisa minyak masak tahap B5 menunjukkan data yang dikehendaki disebabkan oleh ketumpatan, kelikatan kinematik, nilai asid, FFA, takat beku, takat awan hampir sama dengan nilai petrodiesel. Selain itu, campuran tahap B20 biodiesel daripara minyak biji getah menunjukkan sifat kelikatan kinematik dan tahap aliran sejuk tidak lebih daripada 5% daripada nilai petrodiesel. Kedua- dua campuran biodiesel daripada tahap B5 sisa minyak masak dan juga tahap B20 minyak biji getah adalah dalam julat spesifikasi ASTM D6751 dan EN14214.

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ABSTRACT

Biodiesel is a clean burning alternative to mineral diesel fuel that is produced from renewable resources such as vegetable oil or animal fat. Vegetable oils are becoming a promising an alternative to diesel fuel because they are renewable in nature and can be produced locally and environmental friendly as well. This work presents the influence of biodiesel formulation and blending to fuel properties. Two types of biodiesel derived from rubber seed oil and waste cooking oil will be tested according to ASTM D6751 for acid value, FFA, kinematic viscosity, pour point, cloud point, density and calorific value whether as pure biodiesel or as blended with petrodiesel. Throughout these researches, it shows that the blending technique can give the solution on the alternative way to minimize the use of diesel fossil fuel in transportation. The waste cooking oil biodiesel B5 level gives the best result due to the parameter such as density, kinematic viscosity, acid value, FFA, cloud point and pour point of biodiesel almost near to the diesel fuel characteristics. Besides, the blending of rubber seed oil biodiesel B20 shows the good characteristic such as calorific value, kinematic viscosity and cold flow properties are more or less differs in 5 % than the characteristics of diesel fuel. Both biodiesel blends waste cooking oil biodiesel B5 and rubber seed oil biodiesel B20 are in the range of specification of ASTM D6751 and EN14214.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Biodiesel is a clean burning alternative to mineral diesel fuel that is produced from renewable resource such as vegetable oil or animal fat. Vegetable oils are becoming a promising an alternative to diesel fuel because they are renewable in nature and can be produced locally and environmental friendly as well (Ramadhas et. al., 2005). The biodiesel is produced using transesterification process. Transesterification is the chemical reaction between triglycerides and alcohol in the presence of catalyst to produce mono-esters. In recent years, systematic efforts were under taken by many researchers to determine the suitability of vegetable oil and its derivatives as fuel or additives to the diesel. Blending, emulsification, thermal cracking and transesterification are the commonly adoptable methods to use the vegetable oil as fuel in diesel engines.

1.2 Problem Statement

The physical and chemical properties of biodiesel play important role in determination of characteristics in the specification of ASTM D6751 standard and EN 14214 standard. These international standards are taken as a reference for the quality testing in biodiesel production. The biodiesel gives an advantage as an alternative way to reduce the consumption of the diesel fossil. Besides biodiesel can reduce most exhaust emissions, improved lubricity, higher flash point, improved biodegradability and reduced toxicity over conventional diesel fuel. However, there are disadvantage of biodiesel that need to overcome which is some properties of biodiesel.

Pure biodiesel (B100) contains of high viscosity, low calorific value, high cold flow properties and low flash point of vegetable oils biodiesel. These properties will lead to the coking of injectors on piston and head of engine, failure of engine lubricating oil due to polymerization, plugging and gumming of filters, lines and injectors, carbon deposits on piston and head of the engine, excessive engine wear and engine knocking (Mustafa and Havva, 2008). Biodiesel can be used as a blend component in diesel fossil fuel in any proportion. By this blending technique, the better fuel can be obtained. Since nobody has done this research, so the aim for this research is to find the physical and chemical properties of biodiesel blends according to the ASTM D6751 and EN 14214 standards.

1.3 Research Objectives

The research objectives of this study,

1.3.1 To determine the physical and chemical properties of the rubber seed oil biodiesel (B100) and waste cooking oil biodiesel (B100) and relate with the specification of ASTM D6751 and EN14214.

1.3.2 To find out the changing of physical and chemical properties from the blending of rubber seed oil biodiesel and waste cooking oil biodiesel with petrol diesel.

1.4 Scope of the Research

The scope of the research is to investigate the chemical and physical properties which are involve in ASTM D6751 standards and EN14214. The properties of biodiesel can be studies in this research are kinematic viscosity, density, pour point, cloud point, acid value, free fatty acid (FFA) and calorific value in the biodiesel blends. Besides, the biodiesel (B100) will be tested in this research which is waste cooking oil biodiesel and rubber seed oil biodiesel. The trend of properties for waste cooking oil biodiesel blends and rubber seed oil biodiesel blends also include in this work.

1.5 Significance of the Research

The substitution of diesel oil by renewable fuels produced within the country generates higher foreign exchange savings, even for the major oil exporting countries. Therefore, developing countries can use this kind of project not only to solve their ecological problems but also to improve their economy. Carbon and respiration process release carbon dioxide and crops for their photosynthesis process absorb the carbon dioxide. Thus, the accumulation of carbon monoxide in atmosphere reduces.

Directly injected of pure biodiesel to the engine is still not enough for the substitution of diesel fossil fuel due to some problems might happen to the engine. Blending technique can be an alternative way to alter the problem by blending the biodiesel with petrol diesel in percent volume. The lowest level of biodiesel blends such as B5 can be applied to the diesel engine without any modification.

1.6 Conclusion

In this chapter one, the introduction about the research give an overview and explanation about the background of the influence of biodiesel formulation and blending to its chemical and physical properties and problem statement due to the previous case study. Besides, it also stated about the objective of the research, research question, the scope of the research, expected outcome, and significance of the research. For chapter two, about literature review, will be focused more on the previous research on the influence of biodiesel formulation and blending to its chemical and physical properties or other researches that relate to this research. Lastly, chapter three will be covered on research methodology on the influence of biodiesel formulation and blending to its chemical and physical properties.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter two, the main objective is to relate the previous literature about the influence of the biodiesel formulation and blending to its physical and chemical properties. Biodiesel is known as a nonpetroleum diesel. It is produced biologically from the vegetable oil and animal fats using transesterification process. Transesterification process is the chemical reaction between triglycerides and alcohol in the presence of a catalyst to produce mono-esters. Generally, methanol is used to produce biodiesel and the other name for biodiesel is fatty acid methyl esters (FAME). Biodiesel contains about 100 % of FAME often called as B100 and the low concentration of FAME such as 10 % of FAME is known as biodiesel blends.

Usually, biodiesel blends contain a mixture of biodiesel and fossil fuel diesel with the amount of volume blended.

Biodiesel can be categorized into two generations which is first generation of biofuel and second generation of biofuel and this term are in popular usage nowadays. The term of first generation refers to biofuels produced from commonly available, edible feedstocks using well established conversion technologies (Hoekman et. al., 2012). Most of first generation of biodiesel was produced from a food crops. For example the fermentation of sugars from sugar cane, corn, starch and so on to produce ethanol and the biodiesel produced from transesterification of triglycerides which the triglycerides were generated from vegetable oils and animal fats. The term of second generation can refer to biofuels produced from non-food feedstocks, a various types of biomass or produced via advanced processing technology (Hoekman et. al., 2012). Lignocellulose and nonedible triglycerides such as jatropha, rubber seed, waste oil and algae are widely used for second generation of biofuel. Examples of advanced processing technology include catalytic hydroprocessing of triglycerides to produce renewable diesel and thermal conversion such as gasification and pyrolysis of lignocelluloses (Hoekman et. al., 2012).

In recently, the researchers focus on using primary raw materials which are non-food based for any type of biofuel production to avoid the competition of raw material with the food industry. The biodiesel from palm oil has low engine emissions, high oxidation stability apart from the high nitrogen oxide emission which is higher.

2.2 Biodiesel Feedstock

The most significant factors of producing biodiesel are due to the availability of feedstocks for biodiesel production. With this availability of feedstocks for biodiesel production promise the requirement of low production costs in terms of economy and large production scale in terms of quantity. The factors that relate to the availability of feedstock for producing biodiesel are the regional climate, agricultural practices, local soil conditions and geographical locations in the country. Generally, biodiesel feedstock can be classified into several categories such as edible vegetable oil, non-edible vegetable oil, waste or recycled oil and animal fats (Atabani et. al., 2012).

Table 2.1 The List of Categories for Biodiesel Feedstock

Edible oils	Non-edible oils	Animal fats	Other sources
Soybeans	Jathropa curcas	Pork lard	Bacteria
Rapeseeds	Mahua	Beef tallow	Algae
Safflower	Pongamia	Poultry fat	Microalgae
Rice bran oil	Camelina	Fish oil	Tarpenes
Barley	Cotton seed	Chicken fat	Poplar
Sesame	Karanja or honge		Switchgrass
Groundnut	Cumaru		Miscanthus
Sorghum	Neem		Latexes
Wheat	Jojoba		Fungi
Corn	Passion seed		
Coconut	Moringa		
Canola	Tobacco seed		
Peanut	Rubber seed tree		
Palm and palm kernel	Tall		
Sunflower	Coffee ground		
	Nagchampa		

(Source: Atabani et. al., 2012)

Some factors should be considered when comparing the different of feedstocks to produce the biodiesel and these factors must be evaluated based on the full life-cycle analysis. This analysis may includes the availability of land, cultivation practices, energy supply and balance, emission of greenhouse gases, injection of pesticides, soil erosion and fertility, contribution to biodiversity value losses, logistic cost covers transportation and storage, direct economic value of the feedstocks taking into account the co-products, creation or maintain of employment, water requirements and water availability and effects of feedstock on air quality (Atabani et. al., 2012).

2.3 Biodiesel Blend

Biodiesel can be blended with petrol diesel at any level on order to produce a biodiesel blend. The level of biodiesel blend is depends on the percentage in volume of biodiesel in the blends. International practice introduce a single nomenclature to identify the concentration of biodiesel in the blends, known as the letter B with number nomenclature, where letter B represent the biodiesel blends and the number represent the percentage in volume of the biodiesel in the diesel and biodiesel blend. For example, B5 are fuels with the 5 percent in volume of biodiesel and 95 percent in volume of petrol diesel. The study by Yusuf et. al., 2011 mentioned that there are four main levels of concentrations biodiesel used in the fuel market which are pure biodiesel (B100), biodiesel blends (B20 to B30), additive (B5) and lubricity-additive (B2). Commonly the biodiesel blends of 5% and 20% are the most preferable and a lot of researches proved these blends are efficient for the direct use for running the diesel engine. The B5 blend does not require any engine modification due to the physically and chemically properties of biodiesel blends is almost similar petrol diesel (Mustafa and Havva, 2008). Biodiesel is often used as a blend B20 rather than using B100 due to the effect to the fuel system, gums formation and poor start up that lead problem to the diesel engine. Biodiesel blends of up to B20 will reduce the emissions of hydrocarbon, carbon oxide, sulfur dioxide, and particulates as well as improve the engine performance (Yusaf et. al., 2011).

2.4 Biodiesel Standards

The aspect needs to be considered after the biodiesel was produced are the standard of specification for biodiesel. The standard of biodiesel need to be applies due to the ensuring of satisfactory in using biodiesel fuel. It is utilized to protect both biodiesel consumers and producers as well as to support the development of biodiesel industries. The biodiesel fuel specification such as ASTM D6751 for United State standard and EN 14214 for European Union standard was follows as the reference for the biodiesel quality (Hoekman et. al., 2012). These standards describe the physical and chemical properties of the variety biodiesel produced from non-edible and edible oil resources. The physical and chemical properties of biodiesel include calorific value (MJ/kg), flash point (^{0}C), pour point (^{0}C), cloud point (^{0}C), kinematic viscosity (mm^2/s), cetane number, acid value (mg KOH/ g oil), ash content (%), moisture content (%), copper corrosion, carbon residue, distillation range, oxidation stability and so on. Table 2.2 shows the list of parameters in the specification of ASTM D6751 and EN 14214.

Table 2.2 List of Parameters in Specification of ASTM D6751 Standard and EN 14214 Standards.

		ASTM D6751		EN 14214	
Parameters	Units	Limits	Test Method	Limits	Test Method
Flash point	^0C	130 min	ASTM D93	101 min	EN ISO 3679
Cloud point	^0C	-3 to -12	ASTM 2500	-	-
Pour point	^0C	-15 to -16	ASTM 97	-	-
Cold filter pluggin point (CFPP)	^0C	-5 max	ASTM D 6371	-	EN14214
Cetane number		47 min	ASTM D613	51 min	EN ISO 5165
Density at 15 ^0C	kg/m^3	880	D1298	860-900	EN ISO 3675
Kinematic viscosity at 40^0C	mm^2/s	1.9-6.0	ASTM D445	3.5-5.0	EN ISO 3104
Iodine number	g 12/100g	-	-	120	EN14111
Acid number	mgKOH/g	0.5 max	ASTM D664	0.5 max	EN 14104
Oxidation stability		-	-	3h min	EN14112
Stoichiometric air/ fuel ratio	w/w	13.8	ASTM PS 121	-	-
Cold soak filtration	s	360	ASTM D6751	-	-
Carbon residue	%m/m	0.05max	ASTM D4530	0.3 max	EN ISO 10370
Copper corrosion		No 3 max	ASTM D130	Class 1	EN ISO 2160
Distillation temperature	^0C	360	ASTM D1160	-	-
Lubricity (HFRR)	m	520 max	ASTM D6079	-	-
Sulphated ash content	%mass	0.002 max	ASTM D874	0.02 max	EN ISO 3987
Ash content	%mass	-	-	-	-
Water and sedimentation		0.005 vol% max	ASTM D2709	500 mg/kg max	EN ISO 12937
Moisture	wt%	-	-	0.05 max	EN 1412
Monoglycerides	%mass	-	-	0.8 max	EN 14105
Diglycerides	%mass	-	-	0.2 max	EN 14105
Triglycerices	%mass	-	-	0.2 max	EN 14105
Free glycerin	%mass	0.02 max	ASTM D6584	0.02 max	EN 14105
Total glycerin	%mass	0.24	ASTM D6548	0.25	EN 14105
Phosphorus	%mass	0.001 max	ASTM D4951	0.001 max	EN 14107
Calcium	%mass	-	-	-	-
Magnesium	%mass	-	-	-	-
Sulfur (S 10 grade)	ppm	-	-	-	-
Sulfur (S 15 grade)	ppm	150 max	ASTM D5453	-	-
Sulfur (S 50 grade)	ppm	-	-	-	-
Sulfur (S 500 grade)	ppm	500 max	ASTM D5453	-	-

(Source: Atabani et. al., 2012)

Table 2.2 List of parameters in specification of ASTM D6751 standard and EN 14214 standards (continued)

		ASTM D6751		EN 14214	
Carbon	wt%	77	ASTM PS 121	-	-
Hydrogen	wt%	12	ASTM PS 121	-	-
Oxygen	wt%	11	ASTM PS	-	-

(Source: Atabani et. al., 2012)

Most of the countries around the world used either ASTM D6751 or EN 14214 and some of them used their own standard to determine the quality of biodiesel. Furthermore, in many countries, biodiesel standards always change and modifications occurring frequently. Thus, some of these specifications may no longer be as a current standard. For example, in the Table 2.3, the selected country such as Malaysia use the ISO standard for the biodiesel properties but still use ASTM standard for water content and density.

Table 2.3 The Standard for Biodiesel from Selected Country

Fuel property	Unit	Indonesia (SNI Biodiesel No. 04-7182-206)			Malaysia (MS 2008:2008)		
		Min	Max	Test method	Min	Max	Test method
Density	kg/m^3	850 (40 ^{o}C)	890 (40 ^{o}C)	ASTM D 1298, ISO 3675	860 (15 ^{o}C)	-	ISO 3675, ISO 12185,
Kinematic viscosity at 40^{0}C	mm^2/s	2.3	6.0	ASTM D 445, ISO 3104	3.5	5.0	ISO 3104 MS1831
Cetane number		51	-	ASTM D 613, ISO 5165	51	-	ISO 5156, MS1895
Flash point	^{0}C	100	-	ASTM D93, ISO 2710	120	-	ISO 3679e, MS686
Cloud point	^{0}C	-	-	ASTM D2500	-	-	-
Pour point	^{0}C	-	18	-	-	-	-
Cold filter pluggin point (CFPP)	^{0}C	-	-	-	-	15	EN 116
Copper strip corrosion	Rating (3 h at 50^{0}C)	No 3	-	ASTM D 130, ISO 2160	Class 1		ISO 2160, MS 787

(Source: Atabani et. al., 2012)

Table 2.3 The standard for biodiesel from selected country (continued)

Fuel property	Unit	Indonesia (SNI Biodiesel No. 04-7182-206)			Malaysia (MS 2008:2008)		
		Min	Max	Test method	Min	Max	Test method
Carbon residue		-	-		-	-	
in undistilled sample , or	%mass	-	0.05	ASTM D4530, ISO 10370	-	0.3	ISO 10370, ASTM D 4530
in 10% distillation residue	%mass	-	0.3		-	0.05	
Water content	mg/kg	-	-	-	-	500	ISO 12937, ASTM E 203, ASTM D1160

Fuel property	Unit	Thailand (DOEB: 2009)			Vietnam (TCVN 7717:207)		
		Min	Max	Test method	Min	Max	Test method
Density	kg/m^3	860 (15 ^oC)	900 (15 ^oC)	ASTM D 1298	860 (15 ^oC)	900 (15 ^oC)	TCVN (ASTM D 1298)
Kinematic viscosity at 40^0C	mm^2/s	3.5	5.0	ASTM D 445	1.9	6.0	TCVN (ASTM D 445)
Cetane number		51	-	ASTM D 613	49	-	TCVN (ASTM D 613)
Flash point	^0C	120	-	ASTM D 93	130	-	TCVN (ASTM D 93)
Cloud point	^0C	-	-	-	-	Report	TCVN (ASTM D 2500)
Pour point	^0C	-	-	-	-	-	-
Cold filter pluggin point (CFPP)	^0C	-	-	-	-	-	-
Copper strip corrosion	Rating (3 h at 50^0C)	No 1		ASTM D130	No 1	-	TCVN (ASTM D 130)
Carbon residue		-	-	-	-	0.05	TCVN (Astm d 4530)
in undistilled sample , or	%mass	-	-	-	-	-	-
in 10% distillation residue	%mass	-	0.3	ASTM D 4530	-	-	-
Water content	mg/kg	-	500	EN ISO 12937	-	-	-

(Source: Atabani et. al., 2012)

Table 2.3 The standard for biodiesel from selected country (continued)

Fuel property	Unit	Thailand (DOEB: 2009)			Vietnam (TCVN 7717:207)		
		Min	Max	Test method	Min	Max	Test method
Density	kg/m^3	860 (15 ^oC)	900 (15 ^oC)	ASTM D 1298	860 (15 ^oC)	900 (15 ^oC)	TCVN (ASTM D 1298)
Kinematic viscosity at 40^0C	mm^2/s	3.5	5.0	ASTM D 445	1.9	6.0	TCVN (ASTM D 445)
Cetane number		51	-	ASTM D 613	49	-	TCVN (ASTM D 613)
Flash point	^0C	120	-	ASTM D 93	130	-	TCVN (ASTM D 93)
Cloud point	^0C	-	-	-	-	Report	TCVN (ASTM D 2500)
Pour point	^0C	-	-	-	-	-	-
Cold filter pluggin point (CFPP)	^0C	-	-	-	-	-	-
Copper strip corrosion	Rating (3 h at 50^0C)	No 1		ASTM D130	No 1	-	TCVN (ASTM D 130)
Carbon residue		-	-	-	-	0.05	TCVN (Astm d 4530)
in undistilled sample , or	%mass	-	-	-	-	-	-
in 10% distillation residue	%mass	-	0.3	ASTM D 4530	-	-	-
Water content	mg/kg	-	500	EN ISO 12937	-	-	-
Fuel property	Unit	China (GB/T20828-2007)			Republic of Korea (KS M)		
		Min	Max	Test method	Min	Max	Test method
Density	kg/m^3	820	900	GB/T2540	860	900	ISO 3675 (KS M 2002),ISO 12185
Kinematic viscosity at 40^0C	mm^2/s	1.9	6.0	GB/T265	1.9	5.0	ISO 3104 (KS M 2014)
Cetane number		49	-	GB/T386	-	-	-
Flash point	^0C	130	-	GB/T261	120	-	ISO 3679 (KS M 2010)
Cloud point	^0C	-	-	-	-	-	-
Pour point	^0C	-	-	-	-	-	-

(Source: Atabani et. al., 2012)

Table 2.3 The standard for biodiesel from selected country (continued)

Fuel property	Unit	China (GB/T20828-2007)			Republic of Korea (KS M)		
		Min	Max	Test method	Min	Max	Test method
Cold filter pluggin point (CFPP)	^0C	-	Report	SH/T0246	-	0	KS M 2411
Copper strip corrosion	Rating (3 h at 50^0C)	-	1	GB/T5096	-	No 1	ISO 2160 (KS M 2018)
Carbon residue		-	-	-	-	-	-
in undistilled sample , or	%mass	-	-	-	-	-	-
in 10% distillation residue	%mass	-	-	-	-	0.1	KS M ISO 10370
Water content	mg/kg	-	0.05	SH/T0246	-	-	-

(Source: Atabani et. al., 2012)

2.5 The Properties of Biodiesel

In this research, we will focus more on the physical and chemical properties of the palm oil biodiesel from the previous research. The parameter of physical and chemical properties of the biodiesel blending is acid value, FFA, pour point, viscosity, cloud point, density and calorific value.

2.5.1 Calorific Value

Calorific value is the crucial parameter in the selection of a fuel. Calorific value is the amount of heating energy released by the combustion process of a unit value of fuels. Biodiesel contains on average 10-12% w/w oxygen, which leads to proportionally lower energy density and heating value, thus more fuel needs to be injected in order to achieve the same engine power output (Giakoumis, 2013). The calorific value of biodiesel is lower than diesel because of its higher oxygen content. The higher the oxygen content, hence the lower the heating value, the higher the potential for Particulate matter reduction (Giakoumis, 2013). The calorific value does not specify in the ASTM D6751 standard. Table 2.4 illustrates the calorific value for waste cooking biodiesel (B100) and rubber seed oil biodiesel (B100) from the previous work.

Table 2.4 The Value of Calorific Value from Previous Study

Previous work	WCOB,MJ/kg	Previous work	RSOB,MJ/kg
Kannan and Arnand, (2012)	35.82	Ramadhas et. al., (2005)	37.50
Meng et. al., (2008)	32.90	Atabani et. al., (2012)	36.50
Enweremadu and Rutto, (2010)	39.77	Melvin et. al., (2011)	38.20
Muralidharan and Vasudevan, (2011)	35.40	Dilip and Baruah, (2011)	36.50

2.5.2 Kinematic Viscosity

The viscosity of an engine fuel is one of the most critical fuel features. Viscosity is a measure of the resistance of a fluid which is being deformed by either shear or tensile stress. In the case of liquid fuels, the less viscous the fluid is greater of the fluid to movement. In other words, the fluid can move smoothly with the less resistance between the surfaces of contact. The high viscosity will affects the injection process and leads to insufficient fuel atomization. In a diesel engine, higher viscosity leads to less accurate operation of the fuel injectors, and to the poorer