Optimization of working performance of 2-Stroke Bio-Diesel Engine

C.H Patel[a], Himanshu Arora[b]

[a,b]School of Mechanical Engineering, Lovely Professional University, Jalandhar, Punjab-144411, India

Corresponding author E-mail: patel.15755@lpu.co.in

Abstract

Biodiesel is a possible fuel that can be used as an alternative of diesel fuel as it create less pollution and 100% recyclable. The oil which is usually employed for Biodiesel is extorted from natural seeds containing higher fatty acids. Second generation fuel is generally extracted from non edible seeds. Transesterification process is employed for the production of biodiesel. The major advantage of using such fuels is that there is no need to change engine parameters while using such fuels. Emissions are getting reduced by the implementation of biodiesel which leads to clean and green environment. In this paper non edible mustard oils used for the preparation of biodiesel. Blends are prepared by mixing biodiesel (10-30%) with diesel. Engine parameters like indicated power, brake power; brake thermal, mechanical and volumetric efficiencies have been studied at load and no load conditions.

Keywords: Biodiesel, Transesterification, mustard oil, Waste mustard oil, Brake Power.

Introduction

Globally use of petroleum based fuel during past thirty years or so has greatly increased due to human population explosion and growth of industrialization. Which has resulted in diminish of petroleum based fuel reserve and that petroleum based fuel is also responsible for global warming by increased green house gas (GHG) emission. Because of those outcomes, a step is move towards replacement, substitute and renewable source of energy which has lesser impact on environment .Country like India has 2nd populated country in the world and only satisfies or meets 22% demand of crude oil, rest 78% demand of crude oil imported from other country like Saudi Arab, Iraq and Iran. Biodiesel is the one of the best choice as alternative source or blending component of diesel in compression ignition engine and it can work in engine without any modification need [1]. Hence because of some characteristic issues of biodiesel that cannot entirely replaced by diesel fuels, otherwise there are some different benefits of biodiesel over diesel fuel [2]. biodiesel is biodegradable (Of a substance or object capable of being decomposed by bacteria or other living organisms) and will not discharge toxic gas because of lower aromatic and sulfur content than petroleum based diesel fuel and also it has higher combustion efficiency than diesel fuel[3]. Biodiesel has lower exhaust gas emission such as unburned hydrocarbon, monoxide and particulate matter except NOx so lower the green house effect[4]. Generally biodiesel is chemically combination of methyl/ethyl ester with long chain fatty acids and commonly produce from non toxic biological resources such as edible oil, non edible oil [5], animal fats [6], microalgae, or even used waste/used cooking oil [7].Vegetable oil is one of the best options for producing biodiesel because they are renewable in environment [8]. There are two varieties of vegetable oils edible and non edible oils. Mostly edible oil is first choice for biodiesel production because of easy availability in nature and the qualities of produced biodiesel are very much suitable for blending of diesel fuel [9]. But use of edible oil in production of biodiesel cause several difficulties like human food insufficiency in the developing countries and greater impact on forest because more arable land is require for plantation purpose so deforestation is greatly increase in some countries. So in order to diminish this difficult situation, many researches have to be carrying out on non edible oil and also it's not suitable for human consumption because it's toxic in nature [5].But most of non edible oils have high value of free fatty acid so the overall cost for producing biodiesel is become increased because many kinds of chemical process has to be done for biodiesel production [10]. Move towards the animal fats they also have same problem due to the high free fatty acid contain the processing cost for production of biodiesel become increased [11].

Transesterification process has done by three reversible reactions which content conversion of tri-glyceride convert into di-glycerides after that di-glyceride convert into mono-glyceride and finally mono-glyceride covert into glycerol need 3mol of alcohol. Glycerol is obtained as by-product of reaction [12-13].The composition of free fatty acid of parent oil decided the selection of base and acid catalyst reaction. In compared to acid catalyst reaction, base catalyst reaction can obtain high yield of biodiesel and high purity at short time (30-60 min) [14]. Generally CH_3ONa (sodium methoxide), NaOH (sodium hydroxide), KOH (potassium hydroxide) and CH_3OK (potassium methoxide) base catalyst is used in process of transesterification [15]. Objectives of the study are enlisted below:

1. To carry out preparation of the biodiesel through waste mustard oil and fresh mustard oil by transesterification process.
2. To compute yield percentage of biodiesel at different values of molar ratio (1:3,1:6, 1:9) and wt % of KOH (2%,3%) to find optimal values for biodiesel production.
3. To compute properties of the waste mustard oil, fresh mustard oil and extract biodiesel such as viscosity, density, flash point and calorific value.
4. To use the biodiesel as blended fuel (B10, B20 and B30) in commercial diesel engine and to calculate engine performance characteristic parameters like indicated power, brake power, fuel flow, air flow, indicated thermal efficiency, brake thermal efficiency, fuel consumption, mechanical efficiency and volumetric efficiency.

Experimental Setup of Laboratory Scale Setup

Transesterification process of mustard oil is held in laboratory scale setup. In that process 500ml of pure mustard oil or waste mustard oil is taken in conical flask called R B flask of a capacity of 2 liter, KOH and methanol are mixed with different weight percentage (2%, 3%) and molar ratio of methanol to oil (1:3, 1:6, 1:9) respectively, to find out the optimal values of that parameters for higher the yield percentage of biodiesel. That wt % of KOH and molar ratio are calculated from fatty acid profile and formula derived from molar mass of oil and alcohol. Generally R B flask has three neck bottle in which condenser, stirrer motor and thermometer are connected respectively.

The condenser is used to avoid the looses of methanol because the methanol is evaporate above 50˚C temperature, thermometer is used to take the reading of temperature time to time because this transesterification process is held in temperature range of 55 to 60˚C and stirrer motor is used to continuous stirring the oil to equal distribution of the temperature in entire volume of oil.

From the previous literatures review it has to found that, at 55˚C the yield percentage of biodiesel has higher value, stirrer motor rotation speed has plays vital role on production of biodiesel and wt % of KOH has optimal value for production of biodiesel at 2-3 wt/wt of oil and molar ratio has optimal value at 1:6 to 1:9. Figure 6 shows the arrangement of laboratory scale setup.

Material used in Engine Test

1. B10, B20 and B30 prepared by blend of mustard biodiesel and commercial diesel.
2. B10, B20 and B30 prepared by blend of waste mustard biodiesel and commercial diesel.

Figure1: Laboratory Scale Setup

VCR Engine Test Setup:-

VCR engine test setup consist power 5.20 kW at 1500 rpm which is four stroke, single cylinder, constant speed, VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading purpose. Compression ratio can be changed without stopping the engine. Provision is also made for interfacing airflow, Fuel flow, temperatures and load measurement.

The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Gas analyzer is connected at engine exhaust to detect the emission gases such as such as NOx (Nitric oxide), HC (unburnt hydrocarbon), CO_2 (Carbon dioxide), O_2 (oxygen) and CO (carbon monoxide). Table 1 shows the specification of VCR engine test setup.

Table 1: Specification of engine test setup

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel
Product code	234
Engine	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5, Modified to VCR engine CR range 12 to 18
Fuel tank	Capacity 15 lit with glass fuel metering column
Gas analyzer	Detect the emission gas like HC, NOX, O2, CO and CO2

Research Methodology

Transesterification is also named by alcoholysis or esterification process, by which we can decrease the value of viscosity of oil or triglycerides. In that process alcohol is transfer into ester by use of another alcohol that process is also similar to hydrolysis process but in hydrolysis process water is used instead of alcohol [2].Before transesterification process we determine fatty acid profile of pure and waste mustard oil by which we can determine the molecular mass of that respective oil. The value of molecular mass of oil can get help to find the value of methanol at different molar ratio. Molecular mass of mustard oil is 972.67 gm/mole and for waste mustard oil is 973.70 gm/mole, derived from fatty acid profile of oil.

Preparation of biodiesel is held in laboratory scale setup in which methanol of having different molar ratio such as 1:3, 1:6, 1:9 respectively is mixed with homogeneous alkaline catalyst KOH with different wt percentage such as 2% and 3%. The amount of molar ratio and wt percentage of catalyst used has depended on the fatty acid profile of an oil or triglyceride. Volume of methanol which is used in transesterification process is determine by formula which is given below

Molecular ratio of $\frac{oil}{methanol} = \frac{mass of oil}{Molecular mass of oil} \times \frac{Molecular mass of methanol}{mass of methanol}$

Where

Mass of oil = density of oil × volume of oil

Mass of methanol = density of methanol × volume of methanol

Molecular mass of mustard oil = 972.67 gm/mole (derived from fatty acid profile)

Molecular mass of methanol (CH3OH) = 32.04 gm/mole

Results and Discussion

Properties of Mustard and Waste Mustard Oil:-

Mustard seed is give 33% production of oil, that yield of oil is greater than soybean seed that only gives 18-23% yield of oil [16]. Properties like density, flash point, kinematic viscosity and calorific value of mustard and waste mustard oil was calculated given in Table 2.

Table 2: Properties of mustard and waste mustard oil

PROPERTY	Unit	FUEL	
		MO	WMO
Density	gm/ml	0.92	0.906
Kinematic viscosity	mm2/sec	31.55	48
Calorific Value	MJ/kg	38.8	38
Flash Point	^{0}C	268-272	270-278

Gas chromatography method used for determination of fatty acid profile. Fatty acid profile plays a vital role for produced biodiesel when it is run in engine. This profile consist of Saturated Fatty Acids, Mono unsaturated Fatty Acids, Poly Unsaturated fatty acids and Trans fatty acids. In which saturated fatty acid esters have better oxidation stability and higher cetane values, but at low temperature flow properties become poor[16-17]. Fatty acid profile of mustard and waste mustard oil is given in Table 5. From that table unsaturated fatty acid for mustard oil consist acid (88.12%) is higher than saturated fatty acid content (11.22%).

Similarly results found in fatty acid profile of waste mustard oil in which unsaturated fatty acid content (73.71%) is higher than saturated acid content (26.24%). Content of acid in mono-unsaturated acid for both mustard and waste mustard oil is higher than poly unsaturated acid.

Yield of Biodiesel at Different Molar Ratio and Catalyst Concentration:-

Produced biodiesel was purified with wet washing method; water is used as washing agent in this method. Figure-2 shows yield of biodiesel at different molar ratio and catalyst concentration. Mustard oil gives 87.05% and waste mustard oil gives 85.03% yield of biodiesel at 1:9 molar ratio and 2wt% of KOH. Both mustard and waste mustard oil gives maximum yield of biodiesel at 1:9 molar ratio (oil and methanol) and 2 wt% of KOH.

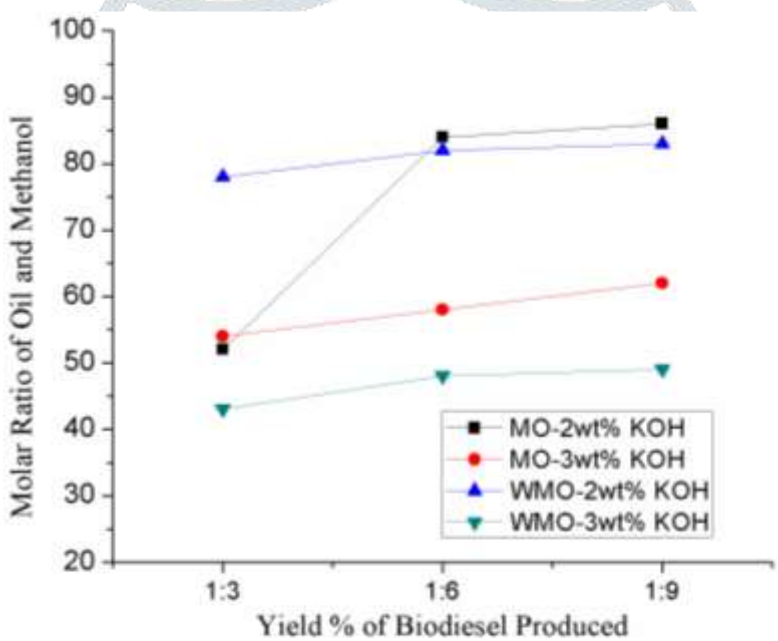

Figure 2: Yield of biodiesel at different molar ratio and catalyst concentration

Properties of Produced Biodiesel and Diesel Fuel:-

After the production of biodiesel it was heated up to 80-90^{o}C for collection of methanol. Methanol gets evaporated at 50^{o}C and collected methanol can be used for further production of biodiesel. Table-3 shows the properties like density, kinematic viscosity, flash point and calorific value for diesel, mustard and waste mustard biodiesel.

Table 3: Properties of diesel, MB and WMB

PROPERTY	Unit	FUEL		
		MB	WMB	Diesel
Density	**gm/ml**	0.882	0.879	0.83
Kinematic viscosity	**mm2/sec**	4.479	4.318	3.5-5
Calorific Value	**MJ/kg**	40.4	40	44
Flash Point	**^{0}C**	160	168	71.2

Performance Characteristics of Engine:-

Produced MB and WMB is blend with commercial diesel fuel at various blend like B10, B20 and B30. This blends were is investigated in KirloskarTV1 engine consisting power 5.20 kW at 1500 rpm which is Four stroke, 1 Cylinder, Constant Speed, Water Cooled diesel Engine of 661cc capacity. Dynamometer is attached in engine assembly for apply various load on engine.

Three loads condition was investigated in engine, they no load condition, 50% load condition and full load condition.

Performance Characteristics at No Load Condition:-

Table-4 shows performance characteristics at No load condition. From Table-4 our investigated points are

- Indicated and break power of blends are higher than diesel fuel.
- Volumetric efficiency of blends is comparatively equal with diesel fuel.
- Mechanical efficiency, indicated thermal and brake thermal efficiency of blends are lower values than diesel values.
- B30 waste mustard biodiesel performance characteristics has higher values than other blends like B20 MB, B30 MB and B20 WMB.

Table 4: Performance characteristic at No load condition

LOAD	FUEL	IP (KW)	BP (KW)	Air Flow (mmWC)	Fuel Flow (cc/min)	IThEff %	BThEff %	Fuel Consumption (Kg/h)	Mech Eff.(%)	Vol Eff.(%)
0%	Diesel	0.71	0.009	92.65	1.11	63.53	7.35	0.04	11.38	85.77
	B10 MB	1.75	0.009	98.37	4.58	58.61	4.37	0.22	7.19	87.4
	B20 MB	2.56	0.009	92.75	6.89	52.77	1.38	0.34	2.67	84.81
	B30 MB	2.06	0.11	93.33	6.66	51.43	2.09	0.34	2.12	85.61

	B10 WMB	1.77	0.009	96.72	5.28	55.87	3.19	0.26	5.76	86.8
	B20 WMB	1.98	0.009	95.01	5.61	56.49	2.77	0.27	4.74	86.32
	B30 WMB	2.03	2.03	96.34	5.8	57.56	2.58	0.3	4.42	86.91

Performance Characteristics at 50% Load Condition:-

Table-5shows performance characteristics at 50% load condition. From Table-5 our investigated points are

- ❖ Performance characteristics like brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and volumetric efficiency for blends are higher values than diesel values.
- ❖ Indicated power and fuel consumption has comparatively equal than diesel values.
- ❖ B30 waste mustard biodiesel performance characteristics has higher values than other blends like B20 MB, B30 MB and B20 WMB.

Table 5: Performance characteristic at 50% load condition

LOAD	FUEL	IP (KW)	BP (KW)	Air Flow (mmWC)	Fuel Flow (cc/min)	IThEff %	BThEff %	Fuel Consumption (Kg/h)	Mech Eff.(%)	Vol Eff.(%)
50%	Diesel	6.57	2.17	80.85	21.98	51.1	16.69	1.08	32.98	82.12
	B10 MB	6.94	2.18	85.07	20.98	54.52	17.07	1.04	31.29	83.8
	B20 MB	6.29	2.18	83.32	19.32	53.78	18.538	0.97	34.52	83.04
	B30 MB	6.03	2.19	83.09	19.45	51.44	18.46	0.98	35.97	82.9
	B10 WMB	1.44	0.06	97.41	4.35	55.79	2.67	0.21	4.87	87.05
	B20 WMB	6.55	2.19	87.4	18.98	55.61	18.44	0.98	33.18	83.73
	B30 WMB	6.59	4.4	85.21	18.5	59.31	19.49	0.93	33	83.77

Performance Characteristics at Full Load Condition:-

Table-6 shows performance characteristics at full load condition. From Table-6 our investigated points are

- ❖ Indicated power of blends have comparatively equal values than diesel values except B30 WMB that have lower value.

- ❖ Brake power of blends has comparatively equal values than diesel values.
- ❖ Indicated thermal and brake thermal efficiency has very lesser values than diesel values.
- ❖ Mechanical efficiency, volumetric efficiency and fuel consumption is higher than diesel values.

Table 6: Performance characteristic at full load condition

LOAD	FUEL	IP (KW)	BP (KW)	Air Flow (mmWC)	Fuel Flow (cc/min)	IThEff %	BThEff %	Fuel Consumption (Kg/h)	Mech Eff.(%)	Vol Eff.(%)
100%	Diesel	8.43	4.28	74.65	2	716.5	363.62	0.1	50.75	80.74
	B10 MB	8.95	4.31	77.92	29	50.82	24.49	1.45	48.02	81.78
	B20 MB	8.17	4.28	75.35	29	46.48	24.36	1.46	52.42	80.58
	B30 MB	8.11	4.3	75.77	28	47.91	25.41	1.42	53.03	80.86
	B10 WMB	8.75	4.3	77.49	28	51.49	25.34	1.4	49.21	81.55
	B20 WMB	8.59	4.28	78.27	27	52.61	26.24	1.36	49.87	81.91
	B30 WMB	8.36	4.31	77.68	27	51.37	26.5	1.37	51.59	81.6

Conclusions

1. Waste mustard and fresh mustard oil gives maximum production of biodiesel at 2 wt% of KOH and 1:9 molar ratio (oil and methanol).
2. Both oil gives approximately same result on that parameters so we can replace fresh mustard oil as waste mustard oil for production of biodiesel so it's also overcome the debate on fuel versus food.
3. In engine performance test brake power, air flow, fuel flow and fuel consumption gives higher values for all blends comparatively diesel fuel.
4. In engine testing, waste mustard biodiesel shows comparatively equal results as mustard biodiesel. So we can replace MB with WBM.

REFERENCES

[1]. Singh A, Smyth BM, Murphy JD. A biofuel strategy for Ireland with an emphasis on production of biomethane and minimization of land-take. Renewable and Sustainable Energy Reviews 2010;14:277-88.

[2]. D. Y. C. Leung, X. Wu, and M. K. H. Leung, "A review on biodiesel production using catalyzed transesterification," *Appl. Energy*, vol. 87, no. 4, pp. 1083–1095, 2010.

[3]. Mudge SM, Pereira G. Stimulating the biodegradation of crude oil with biodiesel preliminary results. Spill Sci Technol Bull 1999;5:353–5.

[4]. Knothe G, Sharp CA, Ryan TW. Exhaust emissions of biodiesel, petrodiesel, neat methyl esters, and alkanes in a new technology engine. Energy Fuels 2006;20:403–8.

[5]. Kumar Tiwari A, Kumar A, Raheman H. Biodiesel production from jatropha oil (Jatropha curcas) with high free fatty acids: an optimized process. Biomass Bioenergy 2007;31:569–75.
[6]. Santos FFP, Malveira JQ, Cruz MGA, Fernandes FAN. Production of biodiesel by ultrasound assisted esterification of Oreochromis niloticus oil. Fuel 2009;doi:10.1016/j.fuel.2009.05.030.
[7]. Issariyakul T, Kulkarni MG, Meher LC, Dalai AK, Bakhshi NN. Biodiesel production from mixtures of canola oil and used cooking oil. Chem Eng J 2008;140:77–85.
[8]. Patil PD, Deng S. Optimization of biodiesel production from edible and non- edible vegetable oils. Fuel 2009;88:1302–6.
[9]. Gui MM, Lee KT, Bhatia S. Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock. Energy 2008;33:1646–53.
[10]. Sahoo PK, Das LM. Process optimization for biodiesel production from Jatropha, Karanja and Polanga oils. Fuel 2009;88:1588–94.
[11]. Singh SP, Singh D. Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: a review. Renewable and Sustainable Energy Reviews 2009;14:200–16.
[12]. Georgogianni KG, Katsoulidis AP, Pomonis PJ, Kontominas MG. Transester-ification of soybean frying oil to biodiesel using heterogeneous catalysts. FuelProcess Technol 2009;90:671–6.
[13]. Furukawa S, Uehara Y, Yamasaki H. Variables affecting the reactivity of acid-catalyzed transesterification of vegetable oil with methanol. Bioresour Technol2010;101:3325–32.
[14]. Labib TM, Hawash SI, El-Khatib KM, Sharaky AS, El Diwani GI, Kader EA.Kinetic study and techno-economic indicators for base catalyzed transester-ification of jatropha oil. Egypt J Pet 2013;22:9–16.
[15]. Tubino M, Junior JGR, Bauerfeldt GF. Biodiesel synthesis with alkaline cata-lysts: a new refractometric monitoring and kinetic study. Fuel 2014;125:164–72.
[16]. Sivakumar P, Sindhanaiselvan S, Gandhi NN, Devi SS, Renganathan S. Optimization and kinetic studies on biodiesel production from underutilized Ceiba Pentandra oil. Fuel 2013;103:693–8.
[17]. Demirbas A. Biodiesel from waste cooking oil via base-catalytic and super- critical methanol transesterification. Energy Convers Manag 2009;50:923–7.