The performance evaluation of diethyl-ether (DEE) additive with Diesel blends using Diesel Engine test rig

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Abstract- The general objective of this paper is to test and compare the performance of Jatropha biodiesel – diethyl-ether and diesel blends with pure petro diesel, using diesel engine test rig with hydraulic dynamometer and roller chassis dynamometer. In the present work diethyl-ether which is also bio based product, as an additive to biodiesel, in anticipation to reduce viscosity, increases cetane number thereby improving the performance. So wide range experimentation is done to critically observe the effect of diethyl-ether addition to biodiesel using diesel engine test rig. In this paper mechanical screw type oil extractor is used to extract the strait Jatropha vegetable oil. The strait vegetable oil is changed into biodiesel by using trans-esterification reaction. Methanol alcohol and potassium hydroxide was used as a catalyst for the reaction. Different amount of DEE, 40ml, 30ml, 20ml, and 10ml per litter was used. The performance of the fuels with additive show that the power output as well as the specific fuel consumption of the B-20 with 40ml of DEE has given the best result next to the petro diesel.

Index terms- Diesel blends, Diesel engine test rig, Diethyl-ether (DEE), Jatropha biodiesel, Oil extractor, Trans-esterification, Vegetable oil.

1. INTRODUCTION

1.1 Literature review: Because of the growing interest for renewable energy sources, biodiesel energy production derived from vegetable oil, animal fat, and used waste cooking oil including triglycerides is proposed as an alternative to petroleum based fuel to reduce greenhouse gas emission, pollution and man's total dependence on petroleum fuel. Bio-diesel is the most valuable form of renewable energy.

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It is environment friendly and ideal for heavily polluted cities and is as biodegradable as salt. Research has found that it produces 80% less carbon dioxide, 100% less sulphur dioxide emissions and has 90% reduction in cancer risk [1]. Use of vegetable oils in diesel engines is not a new development; rather it is as old as the diesel engine itself. Dr Rudolph diesel (1858-1913), the inventor of compression ignition engine (1892 AD) used peanut oil as fuel to run one of the engines in Paris exposition in 1900 AD [2].

It is reported that a dry seed of Jatropha curcas contains about 55% of oil. However, the maximum amount of oil that can be extracted from a given sample of the seed depends on the method of extraction. Two main methods of extracting the oil have been identified [3]. They are the chemical extraction method using solvent extraction with n-hexane and the mechanical extraction method using either a manual ram-press or an engine driven- expeller. Kpikpi has reported that solvent extraction with n-hexane could produce about 41% yield by weight of oil per kg of the jatropha seed [4]. Foidl and Eder reported that the dry seed of J. curcas would yield about 30–38% of crude oil, however, in their study in Nicaragua 30.8% of crude oil by weight was extracted from 12,782 tons of dry weight of Jatropha curcas using an engine driven-expeller [5].

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1.2 Trans-esterification: is the process of exchanging the organic group R'' of an ester with the organic group R' of an alcohol. These reactions are often catalysed by the addition of an acid or base. Trans-esterification is common and well-established chemical reaction in which alcohol reacts with triglycerides of fatty acids (vegetable oil) in the presence of catalyst [6]. For this reaction methanol alcohol and potassium hydroxide is used as a catalyst.

1.3 Additive property: However, there are major drawbacks in the use of biofuel blends as NOx tends to be higher, the intervals of motor parts replacement such as fuel filters are reduced and degradation by chronic exposure of varnish deposits in fuel tanks and fuel lines, paint, concrete, and paving occurs as some materials are incompatible. Here, fuel additives become indispensable tools not only to decrease these drawbacks but also to produce specified products that meet international and regional standards like EN 14214, ASTM D 6751, and DIN EN 14214, allowing the fuels trade to take place. Additives improve ignition and combustion efficiency, stabilize fuel mixtures, protect the motor from abrasion and wax deposition, and reduce pollutant emissions, among other features. Two basic trends are becoming more relevant: the progressive reduction of sulphur content and the increased use of biofuel. Several additive's compositions may be used as long as they keep the basic chemical functions that are active.

TABLE 1
STANDARD ASTM D 6751 REQUIREMENTS

Property	Method	limits	units
Flash point, Close cup	D 93	130 min	^{0}C
Water and sediment	D 2709	0.050 max	% volume
Kinematics viscosity, 40 0C	D 445	1.9-6.0	mm^2/s
Sulphated ash	D 874	0.020 max	Wt. %
Total Sulphur	D 5453	0.05 max	Wt. %
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47 min	
Cloud point	D 2500	Report to customer	^{0}C
Carbon residue	D 4530	0.05 max	Wt. %
Acid number	D 664	0.80 max	Mg KOH/g
Free glycerine	D 6584	0.02	Wt. %
Total glycerine	D 6584	0.240	Wt. %
phosphorus	D 4951	0.0010	Wt. %
Vacuum distillation end point	D 1160	360 ^{0}C max, at 90% distilled	^{0}C

TABLE 2
(A) PROPERTIES OF FUEL USED & DIETHYL-ETHER ADDITIVE

Properties of fuel used			Properties of Diethyl-ether	
Property	Diesel	JOME	Chemical Structure	C_2H_5-O-C_2H_5
Calorific value(kJ/kg)	43200	38600	Specific gravity	0.713
			Viscosity mm^2/sec (20 ^{0}C)	0.23
Specific gravity	0.804	0.862	Auto ignition point ^{0}C	160
			Lower heating value kJ/Kg	33900
Kinematic viscosity (cst) at 40 ^{0}C	3.9	5.2	Cetane number	>125
			Oxygen contain (by wt. %)	21

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Flash point ⁰C	56	179	Boiling point ⁰C	35
Fire point ⁰C	64	187	Stoichiometric A/F ratio	11.1
Cloud point ⁰C	-8	17.4	Flammability Limit (% vol.)	Rich = 9.5 - 36
				Lean = 1.9
Pour point ⁰C	-20	9.3	Latent heat of vaporization kJ/Kg	356
			Calorific value kJ/Kg	33900

2. MATERIALS & METHODS

2.1 Materials: For experiment, Following materials were used

1. Four-stroke diesel engine Test rig, 2. Engine dynamometer, 3. Rota vapor with vacuum pump, 4. Thermometer, 5. Hot plate with magnetic stirrer, 6. Digital balance, 7. Glassware

Figure 1: Experimental setup of Hydraulic dynamometer on diesel engine Test rig

By running the engine with different blends of biodiesel the engine Torque and Power can be measured at different speeds at fixed rack position by adjusting the torque or at constant speed by varying rack position and torque. Brake Specific Fuel Consumption (BSFC) is also calculated from the power and fuel flow rate.

2.2 Method & Procedure

2.2.1. Extraction of oil: - The extraction of the oil from the seeds can be done either by mechanical pressing or by solvent extraction (by pressing the kernels), chemically and enzymatically.

The mechanical oil extraction method was used in this paper. Melkassa agricultural research canter, Ethiopia provided 50 Kg of Jatropha seed. By using locally found screw type oil press, 12 liters of street vegetable oil Extracted from the 50 Kg of the Jatropha seed.

(a) (b)

Figure 2. (a) Screw type oil press (b) Jatropha street vegetable oil

2.2.2. Production of biodiesel: - It includes many steps like trans-esterification, phase separation, washing and drying. Jatropha oil, methanol, KOH, beakers, measuring cylinders, magnetic stirrer, thermometer and digital balance was used for the trans-esterification process.

(a) (b)

Figure 3. (a) Equipment for trans-esterification (b) Trans-esterified biodiesel and glycerine

During the trans-esterification process 1000 ml of Jatropha oil heated up to 70 ^{0}C in a round bottom flask to drive off moisture and stirred with magnetic stirrer. 200ml Methanol of 99.5% purity is used. 20gram of catalyst KOH is dissolved in the Methanol, in a separate vessel and was poured into the round bottom flask of oil while stirring the mixture continuously. The mixture was maintained at atmospheric pressure and 60 ^{0}C for 60 minutes. After completion of trans-esterification process, the mixture is allowed to settle under gravity for 24hours. The products formed during trans-esterification were Jatropha oil methyl ester and Glycerin. The bottom layer consists of Glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil. The upper layer consists of biodiesel, alcohol and some soap. The upper layer which consists of biodiesel, alcohol and some soap is separated.

Washing & Drying the biodiesel: Jatropha methyl ester (biodiesel) is mixed, washed with 50 ^{0}C hot distilled water to remove the unreacted alcohol; oil and catalyst and allowed to settle under gravity for 24 hours. The biodiesel must be washed three times for the perfect removal of the unwanted maters. The washing process is done by spraying the hot distilled water on the top of the biodiesel. Gradually the water precipitates down with the impurities to the bottom of the biodiesel. Finally soap is observed at the bottom of the biodiesel. The biodiesel after the final washing is separated and taken for drying.

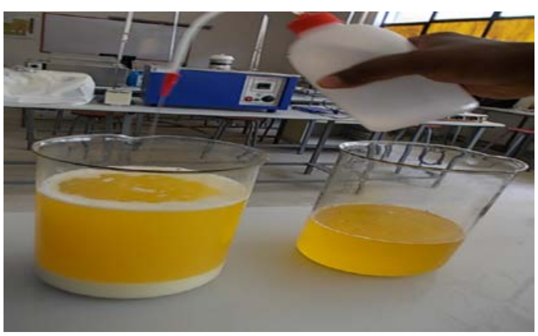

Figure 4. Biodiesel washing

Drying removes moisture and alcohol left over from the washing process. During this process the washed biodiesel is heated to temperature of up to 120 ^{0}C. As a result the alcohol and water evaporated and pure biodiesel is obtained.

2.2.3. Test fuel preparation (characterization): - It is the determination of the properties of produced biodiesel and its blends. B20 means 80% petro Diesel mixed with 20 % Jatropha biodiesel. Six different test fuels were prepared as shown in the table below

TABLE 3
BLEND PROPORTION OF TEST FUELS

Fuel type	petro diesel	Jatropha biodiesel	DEE (diethyl ether)	total
B0	1000 ml	_	_	1000 ml
B20	800 ml	200 ml	_	1000 ml
B20 +5% DEE	800 ml	200 ml	10 ml	1010 ml
B20 +10% DEE	800 ml	200 ml	20 ml	1020 ml
B20 +15% DEE	800 ml	200 ml	30 ml	1030 ml
B20 +20% DEE	800 ml	200 ml	40 ml	1040 ml

3. PERFORMANCE TESTING (EXPERIMENTAL WORK): -

The performance testing of biodiesel and its blends can be done by using an engine test with hydraulic dynamo meter available in the workshop. The intention of this test is to determine the amount of diethyl ether additive in B20 fuel. To test the performance of the fuels, Engine dynamo meter available in workshop was used. The specification of the engine is:-

TABLE 4

TEST ENGINE SPECIFICATION

Engine model	Volks wagon 16D
Fuel system	Diesel with distributor injection pump
Bore x stroke	76.50mm x 86.40
Cylinders	4, inline
Displacement	1.6 liter
Compression ratio	23:1
Injection plunger travel when engine piston is at TDC	1 mm

4. RESULT & DISCUSSION:

Test condition: The test was done at engine temperature of 85 ^{0}C, dynamo meter water pressure 3.5 bar, fuel rack position 50%.

At 50% rack position with no lode applied the Speedo meter reads 2500 Rpm. When load is applied by turning the load application to the increasing direction the speed gradually drops. The test was done at a speed interval of 250 from 2500 to 1000. The time elapsed to consume 10g of fuel during the specified time interval and the corresponding torque is recorded.

TABLE 5

TIME ELAPSED IN SECOND TO CONSUME 10G OF FUEL AT FIXED RACK POSITION WITH VARYING LOAD

Speed in Rpm	B0	B-20	B-20+5%DEE	B-20+10%DEE	B-20+15%DEE	B-20+20%DEE
1000	14.82	15.62	16.45	18.01	14.24	15.12
1250	10.48	11.01	11.97	10.56	12.54	11.02
1500	14.23	13.08	12.89	12.47	13.42	15.17
1750	13.5	15.23	13.73	14.08	16.02	16.96
2000	11.54	14.01	15.64	15.8	15.7	16.08
2250	11.85	12.65	13.71	14.49	16.23	15.5
2500	15	14.61	13.1	12.01	15.6	16.4

Power and specific fuel consumption are obtained by calculation

$$p_b = \frac{2\Pi N T_b}{60000}$$

Where P_b= break Power in Kw, T_b= brake torque in Nm, N=angular speed in RPM

$$b.s.f.c = (10 * 3600)/(p_b * t * 1000)$$

Where b.s.f.c - brake specific fuel consumption, P_b – brake Power, t-time in second elapsed to consume 10gm of fuel

TABLE 6

TORQUE (NM) AT FIXED RACK POSITION WITH VARYING LOAD

Speed in Rpm	B0	B-20	B-20+5%DEE	B-20+10%DEE	B-20+15%DEE	B-20+20%DEE
1000	80	75	77	78	80	80
1250	90	82	85	85	85	89
1500	85	82	80	83	84	85
1750	60	65	66	64	58	63
2000	55	50	52	55	55	56
2250	48	43	43	45	46	47
2500	39	39	39	39	39	39

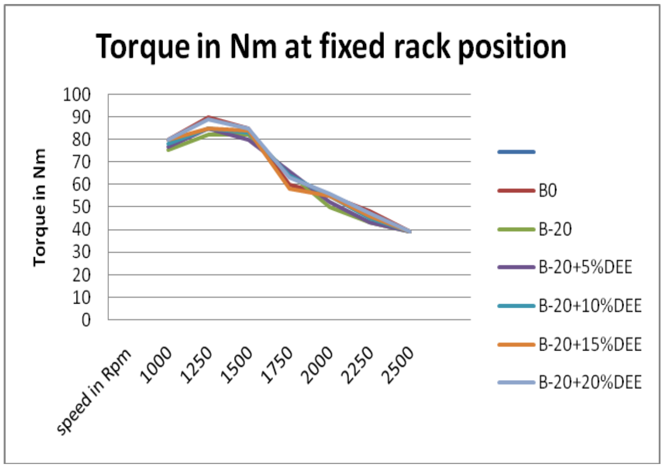

Figure 5.Torque verses speed graph

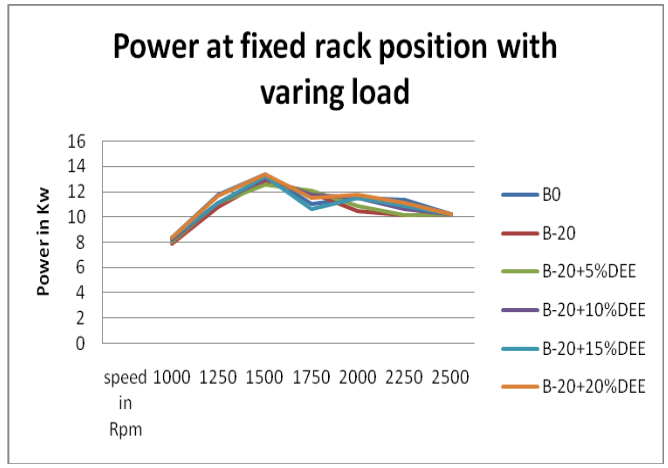

Figure 6. Power verses speed graph

TABLE 7

POWER CONSUMPTION (KW) AT FIXED RACK POSITION WITH VARYING LOAD

Speed in Rpm	B0	B-20	B-20+5%DEE	B-20+10%DEE	B-20+15%DEE	B-20+20%DEE
1000	8.3776	7.854	8.06344	8.16816	8.3776	8.3776
1250	11.781	10.7338	11.1265	11.1265	11.1265	11.6501
1500	13.3518	12.88056	12.5664	13.03764	13.19472	13.3518
1750	10.9956	11.9119	12.09516	11.72864	10.62908	11.54538
2000	11.5192	10.472	10.89088	11.5192	11.5192	11.72864
2250	11.30976	10.13166	10.13166	10.6029	10.83852	11.07414
2500	10.2102	10.2102	10.2102	10.2102	10.2102	10.2102

TABLE 8

SPECIFIC FUEL CONSUMPTION (KG/KWH) AT FIXED RACK POSITION WITH VARYING LOAD

Speed in Rpm	B0	B-20	B-20+5%DEE	B-20+10%DEE	B-20+15%DEE	B-20+20%DEE
1000	0.28995772	0.2934476	0.271403997	0.244717232	0.301767796	0.284204591
1250	0.29158089	0.3046223	0.270302323	0.306393826	0.258015854	0.280408551
1500	0.18947756	0.2136781	0.222248431	0.221430307	0.203305818	0.177736696
1750	0.24252125	0.1984365	0.216780566	0.21799784	0.211419146	0.183852026
2000	0.27081603	0.2453775	0.211350256	0.197798546	0.199058409	0.19088368
2250	0.26861531	0.2808868	0.259169827	0.234320049	0.20465106	0.209730114
2500	0.23505906	0.2413337	0.269151594	0.293579174	0.226018326	0.214993041

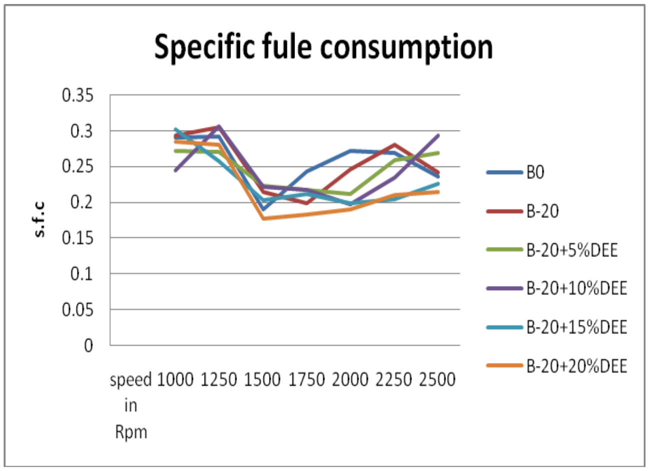

Figure 7. Specific fuel consumption verses speed graph

5. Conclusion:

In this work, trans-esterification reaction was carried out using the non-edible jatropha oil and alkali methoxide. The quantity of potassium hydroxide catalyst for optimal biodiesel yield of 95.5% was 20g/litre at a reaction time of 1 hour, reaction temperature of 65 ^{0}C and molar ratio of oil to methanol as 5:1.

The performance characteristics of diesel, JOME and JOME-DEE blends are analysed and compared. Based on the experimental results, the following conclusions are drawn. The Brake power of B-20 + 20% DEE is found to be higher than that of other biodiesel blends but lower than the B-0. The higher Power after the addition of DEE to JOME is due to its oxygen content and effect on lowering the viscosity of the blend, which led to an improvement in the combustion. The brake specific fuel consumption for B-20 + 10% DEE is lower than that of the others at the maximum load, however at lower load conditions B-20 + 20% DEE gives the lowest break specific fuel consumption.

Recommendation: The mechanical extraction method is very much chipper than the others extraction methods. As the amount of DEE in the B-20 increases the performance of the fuel increases however using more than 40ml of DEE per litter drops the viscosity of the fuel that could affect the lubricating property of the fuel. So B-20+20% DEE (B-20+40ml DEE/litter) is recommended.

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