Experimental Investigation of Performance Parameters of Single Cylinder IC Engine Using Mustard Oil

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Abstract: *The conversion of biomass to energy (also called bio energy) encompasses a wide range of different types and sources of biomass, conversion options, end user applicationsand infrastructure requirements. Mustard oil biodiesel performed very well in vehicles. Fuel consumption increased compared to fossil diesel because biodiesel has slightly less energy per gallon than diesel fuel. The fuel filter had to be changed more often compared to what would normally be experienced with petroleum diesel. This may have been because the fuel filter material did not hold up well with biodiesel. This is due to the combined effects of the fuel density, viscosity and lower heating value of blends. It is observed that dual biodiesel blends BB 10 and BB 20 shows closer BSFC values with diesel than other dual biodiesel blends.*

Keywords: *Biodiesel, IC Engine, Methanol, Mustard Oil*

I. Introduction

India ranks sixth in the world in the term of energy demand accounting for 3.5 % of world commercial energy demand. It is expected to grow at 4.8%. The growth in energy demand in all forms is expected to continue unabated owing to increasing urbanization ,standard of living and expanding population with stabilization not before mid of the current century .

The demand of diesel (HSD) is projected to grow from 52.33 millions of tons in 2006-07 to 61.55 millions of tons in 2009-10. Our crude oil production as per the tenth plan working group is estimated around 33-34 million metric tons per annum. The import bills are rising to $ 15.7 billion or so which is a huge amount for a country like ours. Consumption of diesel can be minimized by implementing biodiesel program expeditiously. [1]

The potential of bio-diesel production from mustard oil have been found to be a promising fuel for diesel engine in a number of studies [2].Mustard (Brassica juncea) is a widely growing seed in Rajasthan, Madhya Pradesh Uttar Pradesh, Haryana, Punjab in India. Many countries consider mustard oil as unsuitable for human consumption as it has a high content of a substance known as Uric Acid which is harmful to the body. Mustard plant is characterized by yellowish green leaves and round stems with long inter-nodes. The grayish brown seeds are tiny and round in shape and on reacting with water emit a strong smell. It is generally used in cooking.[4]

II. Biodiesel

Bio-diesel consists of mono alkyl esters produced from vegetable oils, animal or old cooking fats. Bio-diesel contains no petroleum diesel, but it can be blended with petroleum diesel**.** Mono-alkyl esters of long chain fatty acids (biodiesel) is a promising substitute of petro diesel fuel that can be produced from natural, renewable resources such as wide variety of vegetable oils and animal fats. These resources are biodegradable and nontoxic. The term, biodiesel, was first introduced in the United States during 1992 by the National Soy development Board (presently National Biodiesel Board), which has pioneered the commercialization of biodiesel in the USA [3].

- Bio-diesel is a clean burning fuel
- Bio-diesel does not have any toxic emissions like mineral diesel
- Bio-diesel is made from any vegetable oil such as Soya, Canola, Palm, Coconut, mustard, peanut or from any animal fat like Lard or Tallow.
- Bio-diesel is a complete substitute of Mineral diesel.

III. Organic Chemistry

The major components of vegetable oils are triglycerides. Triglycerides are esters of glycerol with long-chain acids (fatty acids). The composition of vegetable oils varies with the plant source. The fatty acid profile describes the specific nature of fatty acids occurring in fats and oils. The chemical and physical properties of fats and oils and the esters derived from them vary with the fatty acid profile. Trans-esterificationis the process where an alcohol and an ester react to form a different alcohol and a different ester. For bio-diesel, an ethyl ester reacts with methanol to form a methyl ester and ethanol. These ethyl esters react with methanol to form bio-diesel and glycerol. As mentioned above, the purpose of transesterification is to reduce the viscosity of the oil. [5]

The Vegetable oils are extracted from crude oil. Therecrude oil usually contains free fatty acids (FFA), water, sterols, phospholipids, odorants and impurities. Its cancause numerous problems in diesel engines. It alsoincreased viscosity, low volatility and poor cold flowproperties. They lead to severe engine deposits, injectorcoking, piston ring sticking etc. Bio-diesel may beproduced by following four ways: Pyrolysis, Microemulsification, Dilution and Transesterification.[6]

In the present work Transesterification process is used toprepare bio-diesel from mustard oil. It is the process ofusing an alcohol (e.g. methanol, ethanol or butanol), inthe presence of a catalyst, such as sodium hydroxide orpotassium hydroxide, to break the molecule of the rawrenewable oil chemically into methyl or ethyl esters of therenewable oil, with glycerol as a byproduct. Transesterificationreaction for vegetable oil

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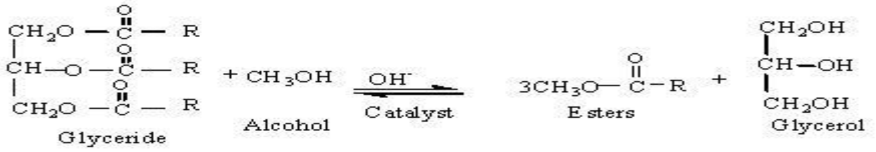

IV. Cost Estimation Of Bio-Diesel

- NaoH 150ml 0.20 (Sodium Hydroxide)
- Methanol 250ml 25 Rs.
- Mustard oil 1 lit. 85 Rs.
- Electric heater 1
- Jar 1
- Thermometer 1

V. Preparation Of Bio-Diesel From Mustard Oil

For the transesterification of mustard oil, Dr. Peeper's style has been followed in our work [7, 8]. First 250 ml (90% pure) methanol was mixed with 150 ml (1 N) NaOH. This mixture was swirled in a glass container until NaOH is fully dissolved in methanol. As this is an exothermic reaction, so the mixture would get hot. This solution is known as meth oxide, which is a powerful corrosive base and is harmful for human skin. So, safety precautions should be taken to avoid skin contamination during meth- oxide producing [9-14].

Next, meth oxide was added with 1 liter of mustard oil, which was preheated about 55 degrees Celsius. Then the mixture was jerked for 5 minutes in a glass container. After that, the mixture was left for 24 hours (the longer is better) (Figures 1) for the separation of glycerol and ester. This mixture then gradually settles down in two distinctive layers. The upper more transparent layer is 100% bio-diesel and the lower concentrated layer is glycerol. The heavier layer is then removed either by gravity separation or with a centrifuge. In some cases if the mustard oil contains impurities, then a thin white layer is formed in between the two layers. This thin layer composes soap and other impurities.Bio-diesel produced in the above process contains moisture (vaporization temperature 100 degree Celsius) and methanol (vaporization temperature 60 degree Celsius) and usually some soap. If the soap level is low enough (300 ppm - 500 ppm), the methanol can be removed by vaporization and the methanol will usually be dry enough to directly recycle back to the reaction. Methanol tends to act as a co-solvent for soap in biodiesel; so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed. Anyway, heating the biodiesel at temperature above 100 degree Celsius would cause the removal of both the moisture and methanol as well. In our study, food grade quality mustard oil was used, other than raw mustard oil to ensure that the vegetable oil contains lesser impurities.

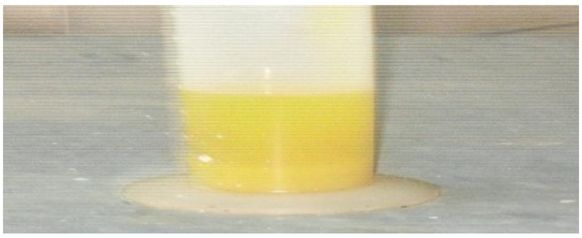

FIG: 1

Table: 1. PROPERTIES OF BIO-FUEL BLENDS, MUSTARD OIL AND BIO- DIESEL

Properties and Standards	Unit	B10	B20	B30	B40	B50	B100	Diesel
Density 35°C (ASTM D4052-11)	kg/m^3	832.2	838.2	840.9	851.6	860.1	880.2	826.2
Specific Gravity (ASTM D5453-09)		0.872	0.899	0.906	0.912	0.918	0.941	0.901
Kinematic Viscosity (ASTM D2161-79)@35°C	mm^2	4.534	5.5918	11.528	11.891	11.982	24.982	3.87
Dynamic Viscosity (ASTM D7042-11a)@35°C	cP	4.056	4.685	9.678	9.857	10.347	22.264	3.34
Calorific Value (ASTM 2382)	MJ/kg	43.12	42.68	42.15	42.09	41.94	39.45	44
Flash Point (ASTM D93-85)	°C	74	78	83	98	111	296	72
Fire Point (ASTM D92-11)	°C	82	95	106	115	130	345	211

VI. Description Of Experimental Setup

FIG: 2

The experimental setup (**Figure 2**) consisted of engine test bed with fuel supply system and different metering and measuring devices with the engine. A water brake dynamometer was coupled with the engine. Load was varied by means of flow control of the dynamometer. Fuel was supplied from an external source. Preheating of fuel was done manually by gas burner. B40 blend was pre- heated at 55°C and B50 blend was preheated at 60°C. However B100 was not possible to use directly in the engine as it causes excessive vibration. Engine speed was measured by digital tachometer. Lube oil temperature and exhaust gas temperature was measured by platinum-type thermocouple. Operating condition of the engine is given in **Table 2.**

TABLE: 2 TECHNICAL SPECIFICATION OF THE ENGINE

Sr. no.	Items	Specifications
1	Model	KIRLOSKAR, AV1
2	Compression ratio	19:1
3	Method of starting	Hand starting
4	Type, no. of cylinders	Vertical – 4 stroke, 1 cylinder
5	Bore x stroke(mm)	87.5x110
6	Cubic capacity	624
7	Maximum power	5 Hp
8	Nominal speed	1500 rpm
9	Cooling system	Water-cooled
10	Fuel filter	Present
11	Lube oil filter	Present

TABLE 3.ENGINE OPERATING CONDITIONS.

Engine Speed	1500
Engine load	1 kg to 7 kg
Fuel Tested	100% diesel, B10, B20, B30, B40 and B50
Lube oil used	SAE 40

VII. Equipments Used For the Experiment

- Single - cylinder four stroke diesel engine,
- Tachometer
- Stop watch
- Bio-diesel
- Diesel
- Plastic Jar
- Nob

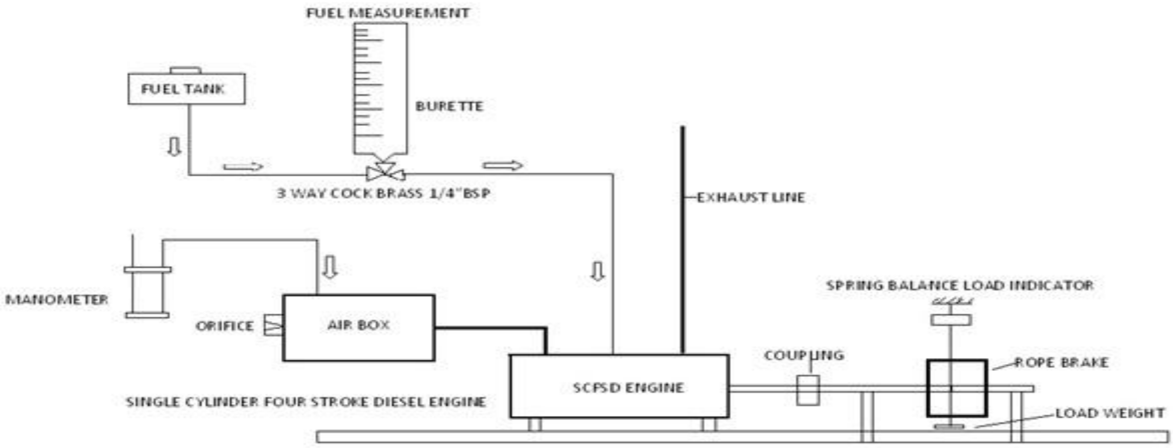

FIG: 3 BLOCK DIAGRAM OF SINGLE CYLINDER FOUR STROKE DIESEL ENGINES

VIII. Results & Discussion

The experiments were conducted using each fuel sample thrice and performance of the engine was evaluated using several parameters such as thermal efficiency, brake specific fuel consumption, exhaust gas temperature, nitrogen oxides and smoke opacity. Brake specific fuel consumption (BSFC) is a measure of volumetric fuel consumption for any particular fuel. Fig. 2 shows the BSFC for dual blended bio fuels and its blends. The engine BSFC decreased with the increase of engine loads. This is due to the combined effects of the fuel density, viscosity and lower heating value of blends. The BSFC of BB 10, BB 20, BB 30, BB 40, BB 50, are 0.765 kg/kWh, 0.325 kg/kWh, 0.338 kg/kWh, 0.341 kg/kWh, respectively whereas the diesel is 0.301 kg/kWh at the maximum load. It is observed that dual biodiesel blends BB 10 and BB 20 shows closer BSFC values with diesel than other dual biodiesel blends.

TABLE: 4 VARIATION OF BSFC WITH BP FOR DIFFERENT FUELS

0 B		10 B		20 B		30 B		40 B		50 B	
BSFC (kg/kW-hr)	BP (kW)	BSFC (kg/kW-hr)	BP (kW)	BSFC (kg/kW-hr)	BP (kW)	BSFC (kg/kW-hr)	BP (kW)	BSFC (kg/kW-hr)	BP (kW)	BSFC (kg/kW-hr)	BP (kW)
3.350	0.242	2.293	0.244	2.719	0.242	2.725	0.244	2.625	0.245	2.508	0.244
1.227	0.724	0.975	0.731	1.218	0.727	1.192	0.729	1.142	0.727	0.962	0.730
0.863	1.231	0.712	1.241	0.936	1.234	0.82	1.237	0.666	1.236	0.795	1.239
0.765	1.729	0.598	1.747	0.831	1.729	0.834	1.737	0.822	1.734	0.701	1.744

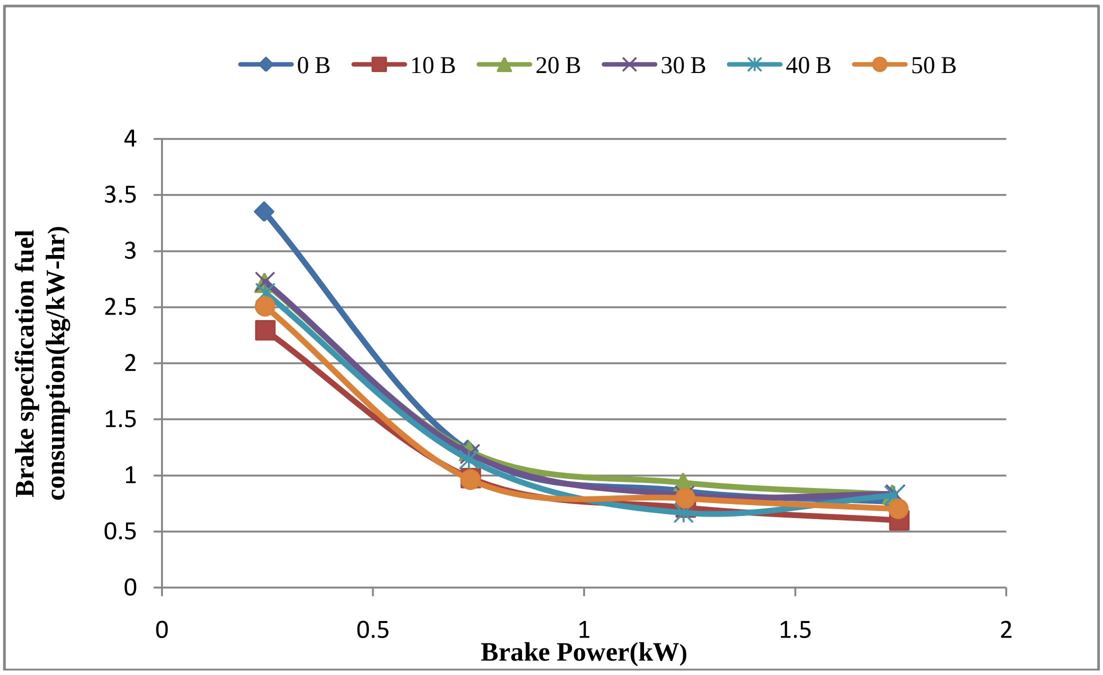

FIG: 4

FIGURES: 4. shows the variation of BSFC with BP for the different fuels. The curve shows that, Bsfc for biodiesel blends is higher at low % load. And it decreases with the increase in % load. it is also observed from the curve that, specific fuel consumption increase with the increase in biodiesel blend. This is mainly due to the relationship among volumetric fuel injection system, fuel specific gravity, viscosity and heating value. As a result more biodiesel blend is needed to produce the same amount of energy due to its higher density and lower heating value in comparison to conventional diesel fuel. Again as biodiesel blends have different viscosity than diesel fuel, so biodiesel causes poor atomization and mixture formation and thus increases the fuel consumption rate to maintain the power.

TABLE: 5 VARIATION OF THERMAL EFFICIENCY WITH BP FOR DIFFERENT FUELS

0 B		10 B		20 B		30 B		40 B		50 B	
BTE	BP(kW)	BTE	BP(kW)	BTE	BP(kW)	BTE	BP(kW)	BTE	BP(kW)	BTE	BP(kW)
2.441	0.242	3.641	0.244	3.101	0.242	3.134	0.244	3.257	0.245	3.421	0.244
6.665	0.724	8.560	0.731	6.921	0.727	7.164	0.729	7.676	0.727	8.918	0.731
9.470	1.231	11.719	1.241	9.008	1.234	9.373	1.237	10.717	1.236	10.785	1.239
10.685	1.729	13.938	1.747	10.144	1.729	10.236	1.737	12.122	1.735	12.237	1.744

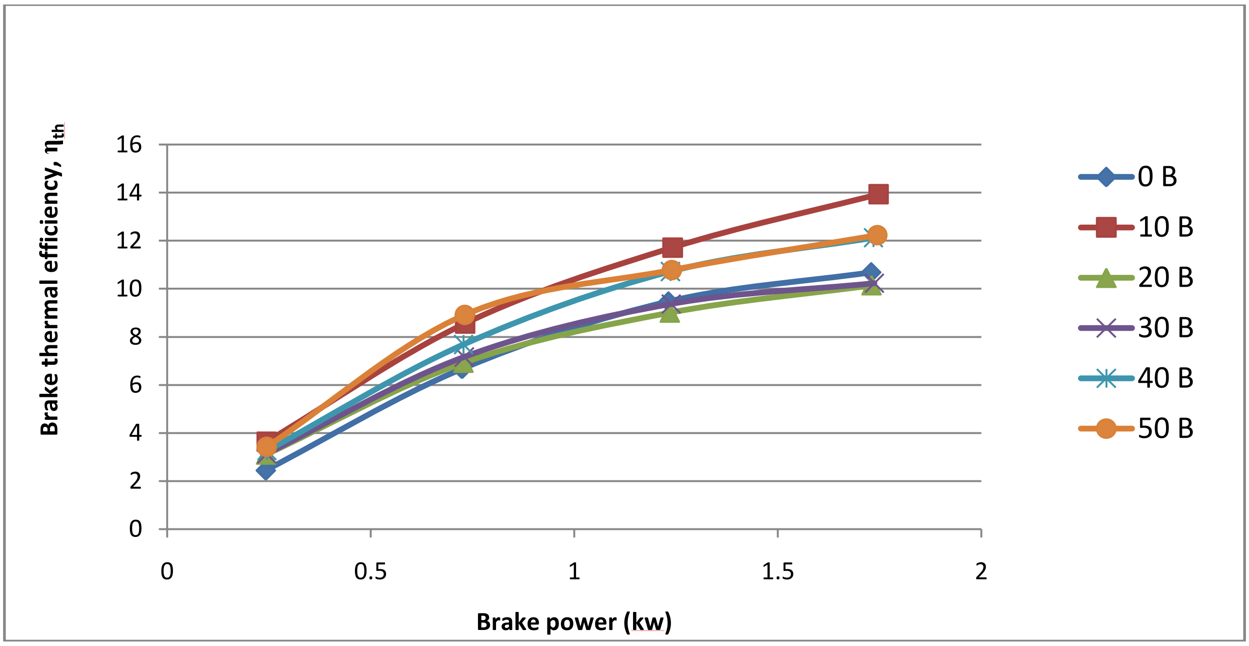

FIG: 5

Figure: 5. shows the relation in between BP and brake thermal efficiency ηb for different fuels. Bsfc is a measure of overall efficiency of the engine. Bsfc is inversely related with efficiency. So lower the value of Bsfc, higher is the overall efficiency of the engine .however, for different fuels with different heating values, the Bsfc values are misleading and hence brake thermal efficiency is employed when the engines are fueled with different type of fuels. From the figure, it is evident that Bsfc for biodiesel blends is always higher and ηb is always lower than that of diesel fuel. This is because biodiesel has lower heating value than conventional diesel fuel. One other cause for lower ηb for biodiesel blends is the poor atomization which is attributed to higher density and kinematic viscosity of biodiesel blends.

TABLE: 6 VARIATION OF EXHAUST GAS TEMPERATURE WITH BREAK POWER FOR DIFFERENT FUELS

0 B		10 B		20 B		30 B		40 B		50 B	
Temperature (°C)	BP(kW)	Temperature (°C)	BP(kW)	Temperature (°C)	BP(kW)	Temperature (°C)	BP(kW)	Temperature (°C)	BP(kW)	Temperature (°C)	BP(kW)
95	0.242	100	0.244	105	0.243	108	0.244	100	0.245	104	0.244
145	0.724	115	0.732	145	0.727	128	0.729	117	0.727	126	0.730
187	1.231	165	1.241	190	1.234	162	1.238	170	1.236	152	1.239
254	1.729	192	1.747	231	1.729	206	1.737	208	1.734	191	1.744

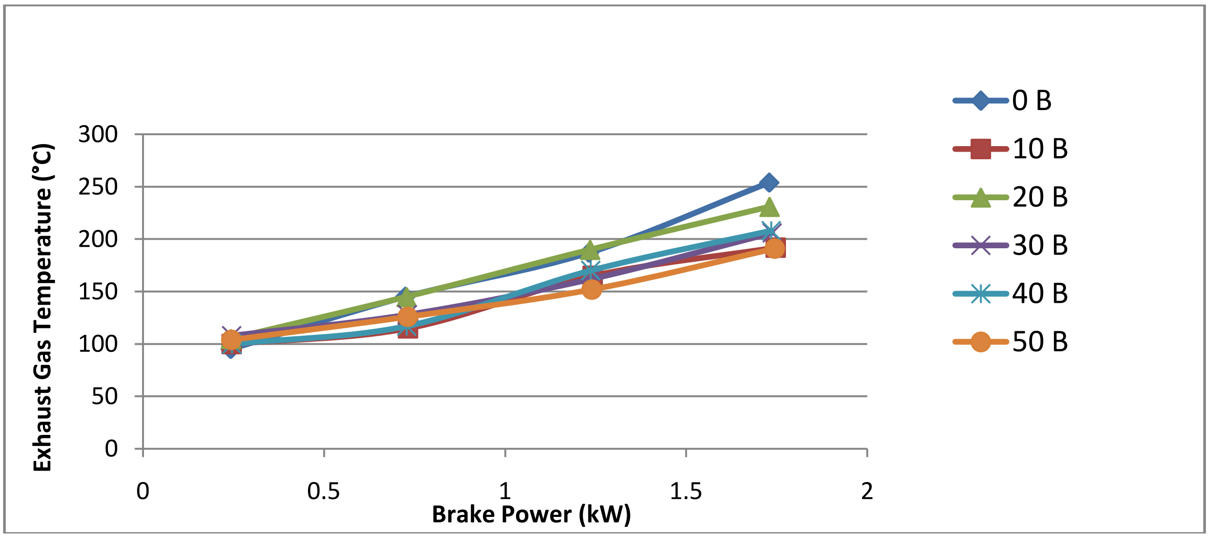

FIG: 6

FIGURE: 6. Depicts about variation in exhaust gas temperature with BP for different fuels. From the curve it is observed that except B30, all other biodiesel blends have higher exhaust gas temperature than diesel fuel. At starting condition, higher exhaust gas temperature but low power output for biodiesel blends indicate late burning to the high proportion of biodiesel. This would increase the heat loss, making the combustion a less efficient. At higher load condition, B30 and B40 have lower exhaust temperature as compared to diesel fuel.

IX. Cost of Running Engines With Different Fuels

Fuel	**Cost (tk/lr)**
Diesel	54
B10	57.10
B20	60.20
B30	63.30
B40	66.40
B50	69.50

The present costing for a diesel engine for bio-diesel obtained from bio-diesel are given above. It is clear from cost that diesel engine running with biodiesel is more costly as comapred to pure diesel fuel.
The present costing of running a diesel engine with bio- diesel blends derived from mustard oil are given in **Table 4.**

From **Table 4** it is clear that, running diesel engine with biodiesel blends is costly as compared to diesel fuel. However, cost can be drastically reduced, if methanol can be recycled after the Trans esterification reaction. Moreover, in our experiment we have used food grade mustard oil. And using raw or unprocessed oil would also cause to decrease the biodiesel production cost.

In India, government grants a huge subsidy on diesel fuel, which causes the lower price for diesel fuel. So a thorough study is required for the feasibility analysis of biodiesel by comparing it production cost with international market price of diesel.

X. Conclusion

- It is possible to run diesel engine with bio-diesel blends.
- In the beginning for smaller values of Brake Power and Load blended biodiesel consumption is higher than the neat diesel consumption which narrows down with higher values of brake power and load.
- BSFC values for smaller load is higher for blended bio-diesel and this gap reduces later for higher value of load.
- Brake power for neat diesel have higher values than blended bio-diesel at all loads and difference of brake power between neat diesel.
- Brake thermal efficiency is higher for neat diesel at all loads and lowers for blends of bio-diesel and difference of brake thermal efficiency between neat diesel and blended bio-diesel decreases as load increases.
- Fuel consumption is nearly same for neat diesel and blended diesel at all BMEP and have lower value at all BMEP for neat diesel.
- Bio-diesel can be produced from mustard oil using trans-esterification reaction.
- BSFC for bio-diesel increases for higher blending of bio-diesel, because of the lower heating value of bio-diesel as compared to diesel fuel.

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