OPTIMIZATION OF BIODIESEL FROM ARGEMONE OIL WITH DIFFERENT REACTION PARAMETERS AND PERFORMANCE ANALYSIS IN CI ENGINE

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Abstract

This experiment work is to investigate the performance parameters of single cylinder, four stroke engine connected to eddy current dynamometer fuelled with argemone biodiesel and blend with diesel fuel under different load condition (0%, 20%, 40%, 60%, 80%, 100%) and constant engine running speed. The performance parameters consist of brake power (BP), brake thermal efficiency (BTHE), and brake specific fuel consumption (BSFC). The argemone mexicana oil was used for production of biodiesel. The transesterification process was used for production of argemone oil methyl ester by using methanol in the presence of sodium metal as a catalyst. The process undergoing various reaction conditions with molar ratio (1:6, 1:3, 1:9 oil to methanol), reaction time (60 min, 90 min, 120 min), reaction temperature (55°C, 65°C, 75°C, 85°C) and catalyst (1%, 1.5%, 2%, 2.5% w/w of oil) effects the fuel properties of argemone biodiesel. The most favorable conditions for transesterification of argemone oil with methanol in the presence of sodium metal as a catalyst was found with molar ratio 1:6 (oil to methanol), reaction time 120 min, reaction temperature 75°C and catalyst 1.5% (w/w of oil). The fuel properties were calculated and compared with Diesel. The result shows that argemone biodiesel blend (AB10 and AB20) have improved fuel property and brake thermal efficiency, brake power and specific fuel consumption value closer to diesel value.

Keywords: *Argemone mexicana oil, Transesterification, Sodium metal Catalyst, Methyl ester, Biodiesel Properties, Engine Performance.*

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1. INTRODUCTION

The worldwide has increased demand of energy supply of fossil fuel source such as petroleum, coal and natural gas. Highly dependency on fossil fuel leads to increase the cost of petroleum, environmental degradation and their import bill [1]. Hence long period energy security is required to develop a new alternative fuel. Biodiesel is a biodegradable, eco-friendly, non-toxic, clean burning and an alternative fuel for diesel engine [2]. It is derived from the different types of vegetables oil (edible and non-edible oil) and animal fats. Different methodologies to produce Biodiesel are [3]:

i. Direct use/blending
ii. Heating
iii. Micro-emulsion
iv. Pyrolysis
v. Transesterification

In the *direct method* straight vegetable oil is used in the diesel engine without any engine modification. The main advantage of this method is complete accessibility and renewability. The straight vegetable oil arises few problems in engine like injector coking, ring sticking, poor atomization and improper combustion due to high viscosity and density of vegetable oil.

Heating is the process in which the viscosity of the vegetable oil varies with the temperature, affecting the efficiency of the engine.

Pyrolysis is the process of conversion of one substance into another substance using heat. Catalyst is used to increase the rate of reaction. Lower hydrocarbons are obtained as the product of pyrolysis of vegetable oil that can be used as a fuel.

In *Micro emulsion*, colloidal dispersion of fluid microstructures (1-150 µm) in solvent forming two immiscible phases take place.

Transesterification is a chemical reaction in which the vegetable oil, a triglyceride react with alcohol (methanol or ethanol) in the presence of catalyst (homogenous and heterogeneous), producing a mixture of fatty acid (methyl or ethyl ester) and glycerol. Different parameters considered during the transesterification reaction are:

i. Molar ratio (vegetable oil to alcohol)
ii. Reaction time
iii. Reaction temperature
iv. Stirring speed
v. Catalyst (homogenous and heterogeneous)
vi. Catalyst concentration (% w/w of oil)

Argemone mexicana is used as non-edible oil resource for the production of biodiesel. Argemone mexicana belongs to papveraceae (poppy) family and the entire species belong to the mexicana prickly poppy. It is commonly known as Shialkanta and Satyanashi in India. In India it is found on the road side, waste land and field. This plant have yellow flower, branching herb with yellow juice and height varies between 0.3 to 0.12 meters. The plant is self-productive [5]. The argemone oil consists of linoleic acid (54-61%), oleic acid (21-33%) and toxicity attributes mainly two alkaloids, sanguinarine and dihydro-sanguinarine [6]. The aim of this work is to find optimum conditions and properties of argemone oil methyl ester. The properties are compared with Diesel Fuel and show that argemone biodiesel meet the properties of diesel standard fuel.

Table -1: Fatty acid composition of argemone oil [9]

Property Fatty acid composition (%)	Argemone oil
Oleic acid (C 18:1)	40.0
Linoleic acid (C 18:2)	36.6
Palmitic acid (C 16:0)	14.7
Stearic acid(C 18:0)	6.75
Palmitoleic acid(C 16:1)	1.3
Linolenic acid (C 18:3)	0.3
Arachidic acid (C 20:0)	0.3
Behenic acid (C 22:0)	0.2
Myristic acid (C 14:0)	0.1

2. MATERIALS AND METHOD

The argemone mexicana seeds were purchased from local market in hoshiarpur. Argemone oil was extracted using Solvent Extraction Method with petroleum esters and hexane as a solvent. The value of free fatty acid of argemone oil was less than 2% hence single step transesterification method was used for production of biodiesel. In this method, transesterification of non-edible oils, triglyceride reacts with three molecule of methanol in the presence of homogenous as catalyst, producing a mixture of three parts of fatty acid methyl ester and one part of glycerol. The triglyceride was converted into mono-alkali ester and glycerol. The alcohol (methanol and ethanol) and catalyst (sodium hydroxide, potassium hydroxide and sodium metal) were provided in the laboratory. The entire experiments were performed in SSS NIRE (Sardar Swarn Singh National Institute of Renewable Energy) Kapurthala, Punjab.

Formula:

$$\textbf{Acid Value} = \frac{\textbf{Volume of KOH used} \times 0.1 \times 56.1}{\textbf{Weight of Sample}}$$

$$\textbf{Free Fatty Acid Value} = \frac{\textbf{Acid Value}}{2}$$

Fig -1: Argemone Mexicana Plant.

Fig -2: Argemone mexicana seeds.

Fig -3: Argemone mexicana oil.

2.1 Production of Biodiesel for Argemone oil

Feedstock : Argemone mexicana oil
Instrument : Redley reactor
Base catalyst : NaOH, KOH, NA metal of 1%, 1.5%, 2%, 2.5% w/w of oil
Reactant : 1:6, 1:3, 1:9 (oil to methanol)

2.2 Biodiesel Setup

The reaction was carried out in Biodiesel Redley Reactor equipped with reflux condenser, magnetic stirrer and thermometer. It consists of water jackets, external heater and condenser. The suitable mixing and turbulence for accelerating the reaction was done by supplementary impeller, attached mechanically to spindle.

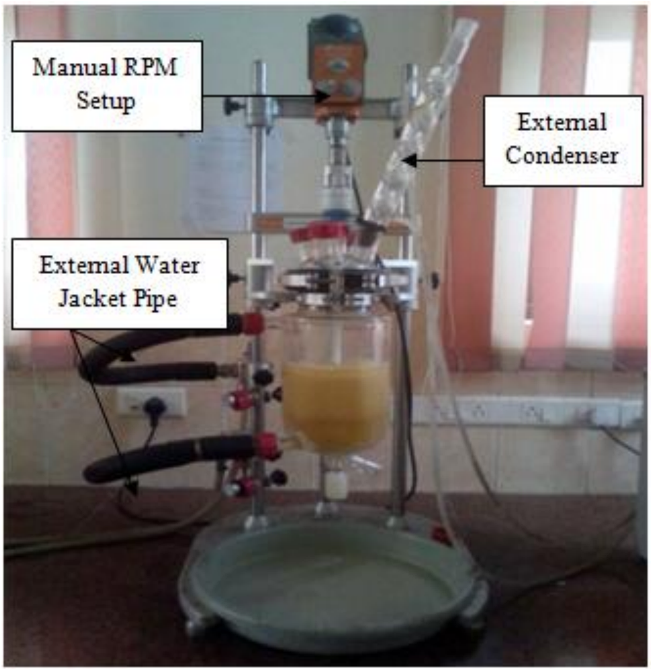

Fig -4: Biodiesel Setup

2.3 Transesterification Process

During experiment, 1000 ml of argemone oil was taken in the biodiesel preparation unit and preheated at 75°C for number of experiment. Preheating was used to eliminate unnecessary moisture content from the oil. According to molar ratio 1:3, 1:6, 1:9, 1:12 (oil to methanol ratio), take 151 ml, 302 ml, 454 ml 605 ml of methanol and catalyst concentration 1%, 1.5%, 2%, 2.5 (9.1 gm, 13.65 gm, 18.29 gm and 22.75 gm w/w of oil) of sodium hydroxide, potassium hydroxide, and sodium metal in the three different beaker and stir until the catalyst gets fully dissolved. The sodium hydroxide, potassium hydroxide and sodium methoxide solution were poured into the hot argemone oil. The reaction temperature was maintained at varies 55°C, 65°C, 75°C, 85°C steady conditions and stirring speed was manually set to constant 650 rpm. Water bath (external heater) and reflux condenser were switched on after proper closing of the flask. The purpose of external heater unit was to maintain constant temperature of reaction and of condenser is to reflux back the vaporized methanol particles into the reactor. The whole mixture was continuous stirred at 650 rpm for two hours. The mixture takes 24 hours to settle down. After 24 hours, two layers are formed. Top layer was biodiesel and bottom layer consist of glycerol and soap. The bottom layer was taken out and the top layer was washed for 10-15 times with hot water. Even after washing process small amount of alcohol and water contents were present in the biodiesel. These contents were removed using oven kept at 110°C, thus obtaining pure biodiesel.

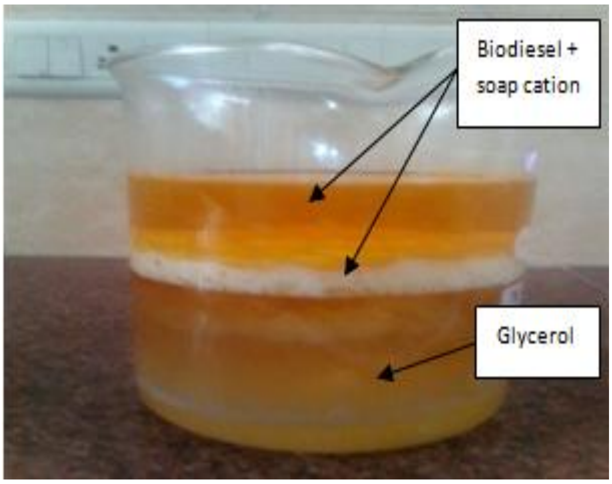

Fig -5: Biodiesel and Glycerol.

Fig -6: Soap and Glycerol Sepration by washing.

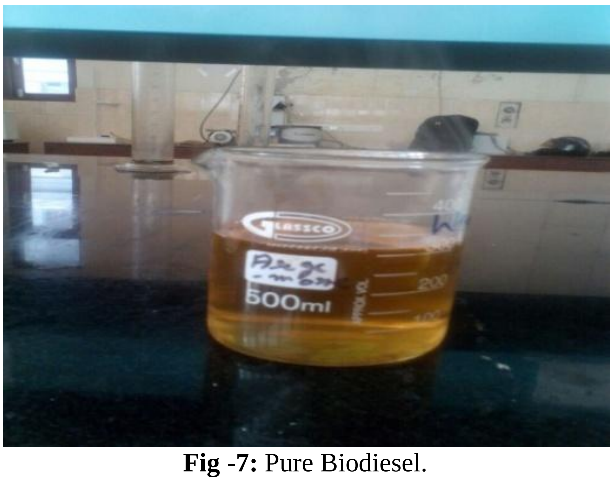

Fig -7: Pure Biodiesel.

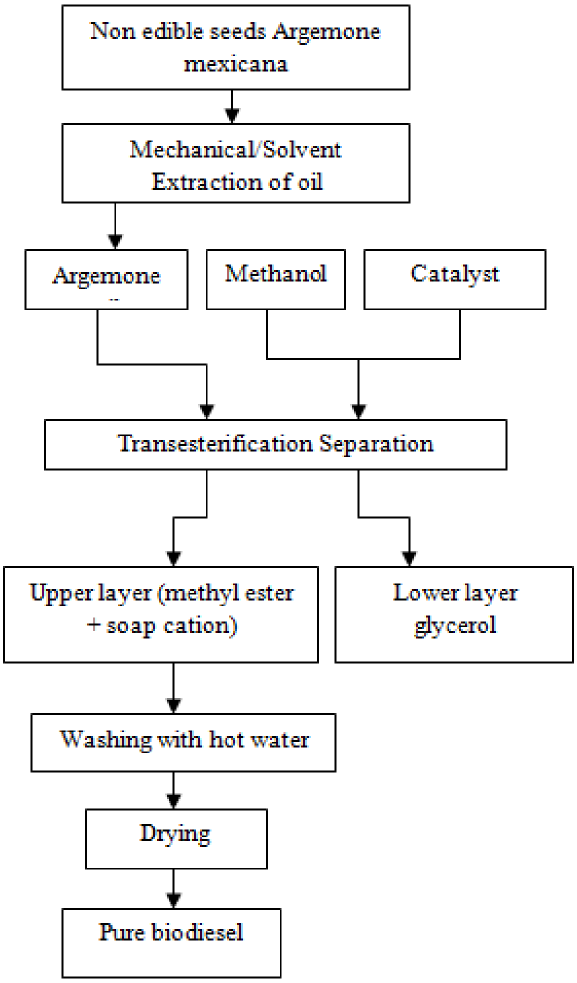

Fig -8: Process for Production of Biodiesel from Argemone oil.

3. PERFORMANCE PARAMETERS ANALYSIS OF CI ENGINE

3.1 Expermental Fuel

In this research investigation five blends were prepared 10% (v/v) argemone biodiesel with 90% (v/v) diesel fuel denoted by AB10 (argemone biodiesel blend). The experiment were conducted using diesel and argemone blend with diesel AB10, AB20, AB30.

3.2 Expermental Setup and Procedure

The experiment setup consist of single cylinder, four stroke, water cooled diesel engine connected to eddy current type dynamometer. The engine specification are shown in table 2. The crank angle sensor, load cell are fitted on the dynamometer and piezosensor fitted on the engine. The engine running speed is constant at 1500rpm. The "EnginesoftLV" software was used performance analysis for engine. The experiment were conducted using diesel and argemone blend with diesel AB10, AB20, AB30 under different load conditions (0%, 20%, 40%, 60%, 80%, 100%) at constant speed 1500 rpm. The experimental setup is shown in figure 9.

Table -2: Engine Specification.

Engine	Kirloskar engine setup 1 cylinder, 4 stroke
Power rating	3.5KW
engine speed	1500RPM
Cylinder bore	87.50 mm
Stroke length	110.00 mm
Swept volume	661.45 cc
Cooled type	Water cooled
Compression ratio	17.5
dynamometer	Type eddy current , water cooled, with loading unit
Load indicator	Digital, supply 230 AC
Rotameter	Engine cooling 40-400LPH, Calorimeter 25-250 LPH
software	"EnginesoftLV" Engine performance analysis software

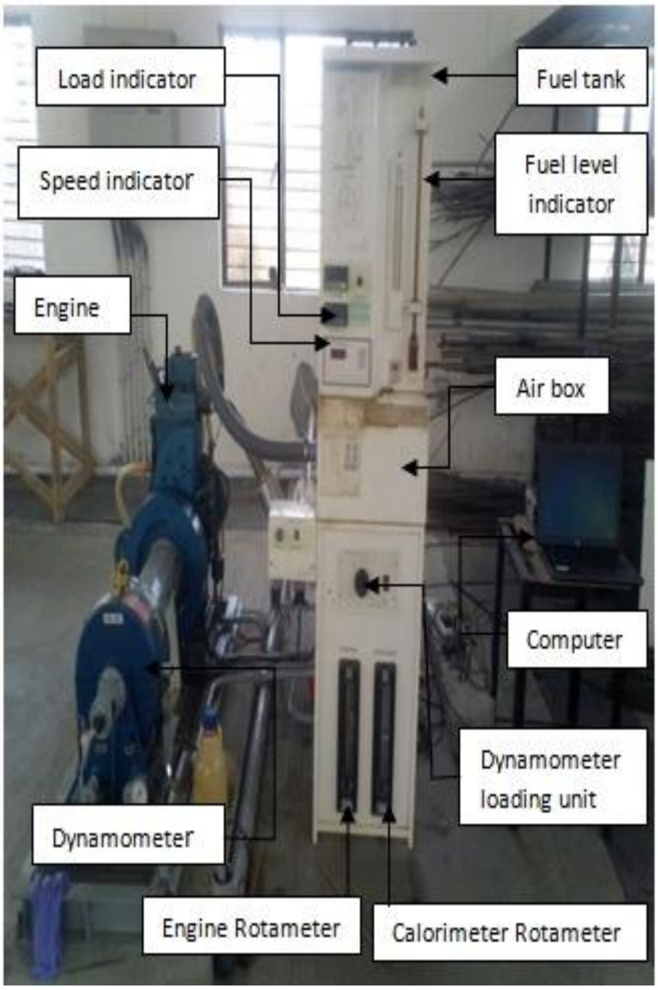

Fig -9: Experimental Setup.

Table -3: Property of argemone oil, biodiesel and blends in comparison with diesel

Test	Unit	Test method	Argemone oil	AB100	AB 10	AB 20	AB 30	Diesel
Density at 40 ºC	g/cm³	ASTM D1250	0.905	0.868	0.822	0.8267	0.832	0.821
API Density at 15 ºC	g/cm³	ASTM D1250	0.92182	0.886	0.8391	0.8449	0.850	0.808
Specific Gravity at 40 ºC	--------	ASTM D 1250	0.9122	0.875	0.8272	0.8382	0.8388	0.814
Kinematic Viscosity at 40 ºC	cst	ASTM D446-12	35	5.07	2.97	3.22	3.30	2.63
Carbon Residue	%wt	ASTM D4530	0.61	0.02	0.028	0.032	0.04	0.01
Flash Point	°C	ASTM D92-12B	220	130	75	83	95	65
Molecular Weight	g/mol		730	-----	-----	-----	----	230
Moisture Content	%wt	ASTM E-871	0.7	0.2	0.028	0.034	0.043	0.02
Acid Value	mgKOH /g	ASTM D 974N	4.7	0.34	0.015	0.21	0.35	0.01
FFA	%		2.35	0.25	0.059	0.105	0.175	0.05
Calorific Value	MJ/kg	IS: 1359-1959, BS 1016;Part 5.1967 IP 1263T	36.72	39.41	42.3	41.36	40.56	43
Fire point	°C	ASTM D92-12B	230	138	78	87	105	68

4. RESULT AND DISCUSSION

4.1 Optimization of Biodiesel with Different Reaction Parameters

In this optimization of biodiesel with various reaction parameters was discussed.

4.1.1 Effect of Reaction Temperature on Biodiesel Yield and Kinematic Viscosity

The kinematic viscosity and biodiesel yield changes with change in reaction temperature. Reaction temperature varied between 55-85ºC for different experiments. The biodiesel yield decreases with the increase in reaction temperature. The biodiesel yield was highest and kinematic viscosity was smallest under the optimum reaction temperature at 75ºC. The effect of reaction temperature on the biodiesel yield (%) and kinematic viscosity was shown by figure (10 & 11).

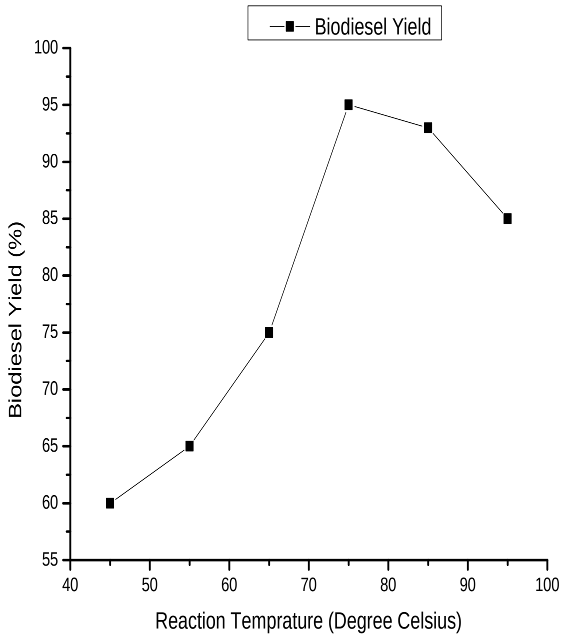

Fig -10: Effect of reaction temperature Vs Biodiesel Yield.

4.1.2 Effect of Molar Ratio on Biodiesel Yield and Kinematic Viscosity

Different type of molar ratio 1:3, 1:6, 1:9 (oil to methanol) were used during the different experiment conducted. The optimum ratio of maximum conversion rate was 1:6 (oil to methanol).

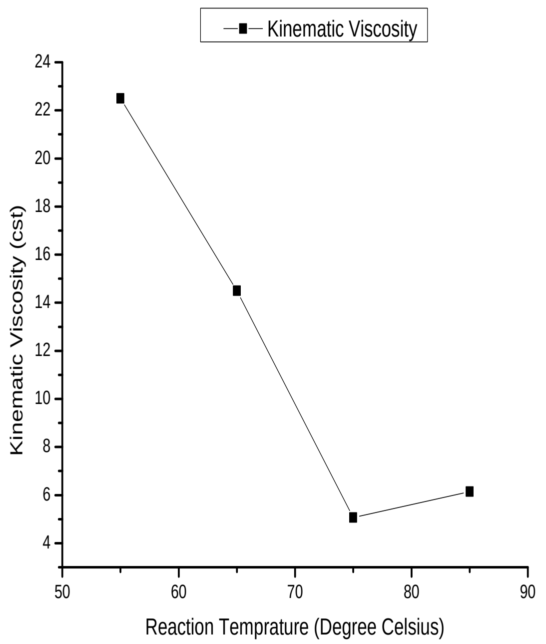

Fig -11: Effect of Reaction Temperature Vs Kinematic Viscosity

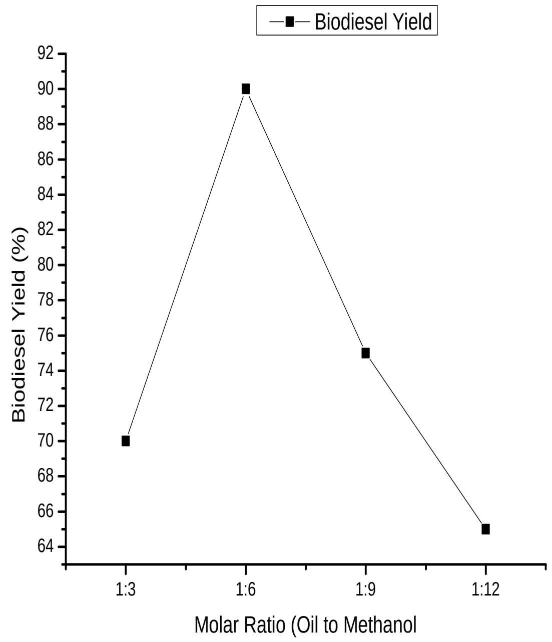

Fig -12: Effect of Molar Ratio Vs Biodiesel Yield.

Higher molar was used during experiment, the density difference between upper layer (biodiesel) and lower layer (glycerol) becomes much less. The separation becomes very difficult and conversion rate decrease. High amount glycerol content in the biodiesel leads to higher kinematic viscosity. The optimum molar ratio was 1:6 (oil to methanol) gives90% yield of biodiesel and reduced kinematic viscosity. The effect of molar ratio on biodiesel yield (%) and kinematic viscosity were shown in figure (12 & 13).

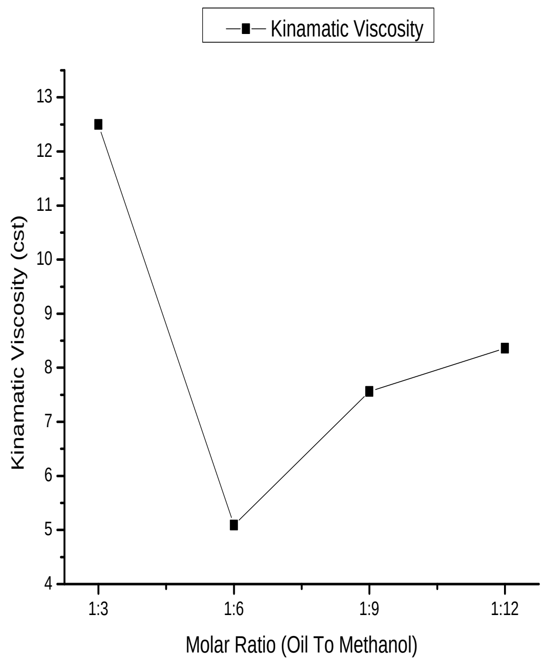

Fig -13: Effect of Molar Ratio Vs Kinematic Viscosity

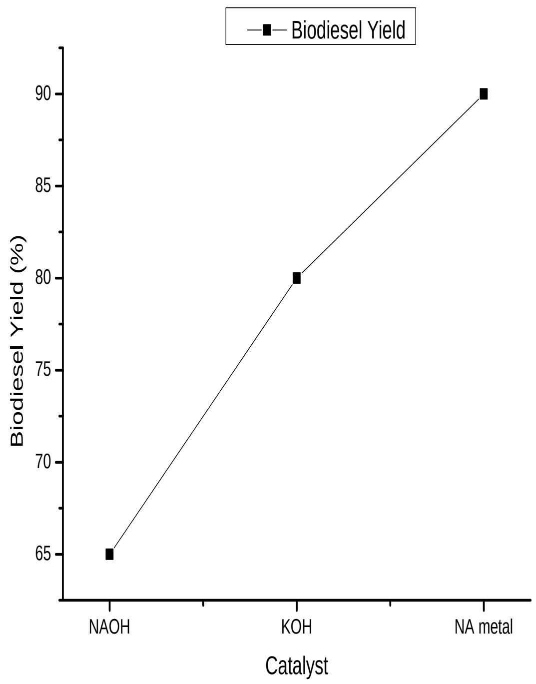

Fig -14: Effect of Catalyst Vs Biodiesel Yield.

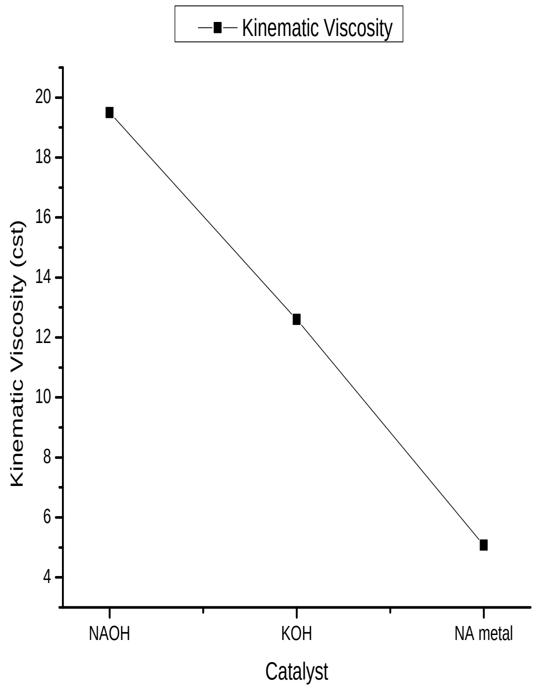

Fig -15: Effect of Catalyst Vs Kinematic Viscosity

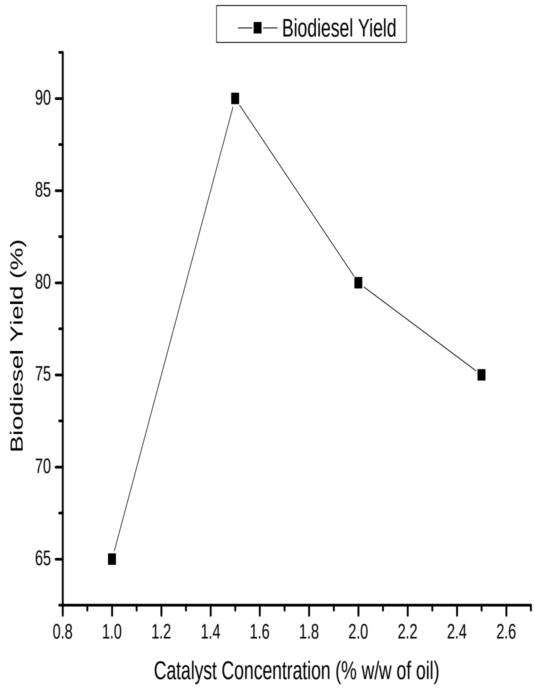

Fig -16: Effect of Catalyst Concentration Vs Biodiesel Yield

4.1.3 Effect of Catalyst Concentration on Biodiesel Yield and Kinematic Viscosity

During the production of biodiesel three types of catalyst NAOH, KOH, NA metal and catalyst concentration 1.5, 2, 2.5% (w/w of oil) were used. Maximum biodiesel yield is obtained for the catalyst NA metal with concentration 1.5% (w/w of oil) react with alkali catalyst) that decreases biodiesel yield and kinematic viscosity increased [10]. The effect of If high amount of catalyst concentration was used, it will produce more soap formation (extra triglyceride to catalyst and catalyst concentration on biodiesel yield (%) and kinematic viscosity were shown in figure (14, 15, 16 &17).

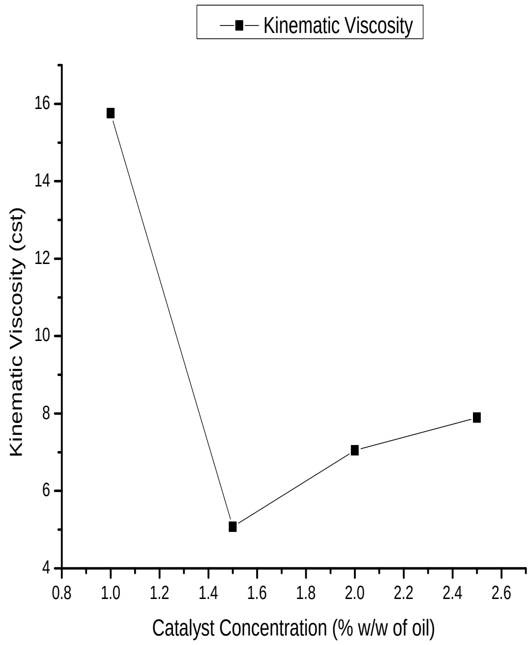

Fig -17: Effect of Catalyst Concentration Vs Kinematic Viscosity.

4.2 Engine Performance

The single cylinder CI engine performance parameters of argemone biodiesel was evaluated in terms of Brake power, brake thermal efficiency and brake specific fuel consumption at different loading (no load, 20%, 40%, 60%, 80%, 100%) conditions.

4.2.1 Brake Power

The brake power was increased with increase in load. The brake power was maximum value (4.27 KW)for AB20 at full load condition. The brake power was maximum due to better combustion and high amount of heat content in the biodiesel.

4.2.2 Brake Thermal Efficiency

The brake thermal efficiency was increases with increase in load on engine. The brake thermal efficiency was maximum for AB20 (31.95%) at full load conditions. The brake thermal efficiency for AB20 was maximum than that of diesel fuel due -to high amount of oxygen content are present in the argemone biodiesel fuel. This value indicates that decrease in heat loss and increase power output with maximum load condition. For AB30 BTE was decreased than that of diesel due to lower calorific value of fuel.

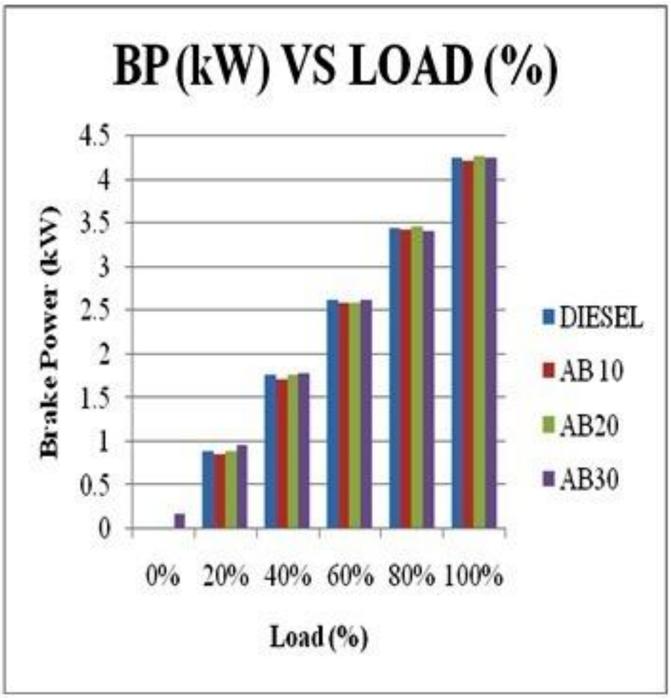

Fig -18: Variation of BP (kW) vs Load (%).

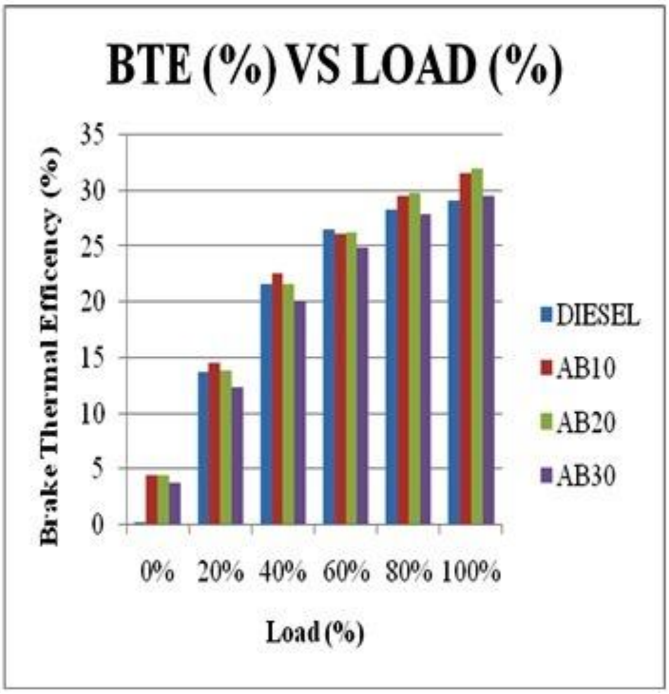

Fig -19: Variation of BTE (%) vs Load (%)

4.2.3 Specific Fuel Consumption

The specific fuel consumption was decreased for different load conditions. The specific fuel consumption value was slightly higher than that of diesel fuel for AB10, AB30 but AB20 value was lower than that of diesel fuel at full load condition. Specific fuel consumption value was lower because of high amount of oxygen contant present in the biodiesel they lead to proper combustion and decrease the specific fuel consumption value.

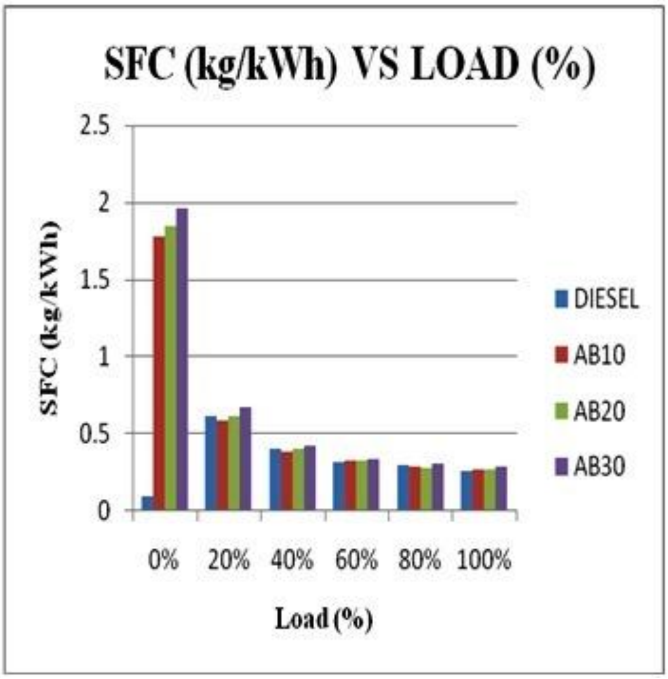

Fig -20: Variation of SFC (kg/kWh) vs Load (%).

5. CONCLUSION

In this study the optimum condition for production of biodiesel from argemone oil and performance analysis on single cylinder CI engine fuelled with argemone biodiesel blends with diesel , the following conclusion have been made in this work

1. The production of biodiesel was highest by single step transesterification of argemone oil with methanol in the presence sodium metal as a catalyst. The biodiesel yield of maximum 90% and kinematic viscosity of minimum 5.07 cst were obtained molar ratio (1:6 oil to methanol) at 75°C.
2. The optimum condition for production of biodiesel were 1:6 oil to methanol ratio, catalyst sodium metal, catalyst concentration 1.5% w/w of oil, reaction time 2 hour, reaction temperature 75ºC, and stirring speed 650 rpm.
3. The brake thermal efficiency and brake power of was maximum for AB20 at full load conditions. Due to high amount of oxygen content are present in the fuel, they lead to proper combustion and better atomization of fuel.
4. The specific fuel consumption was decreased for AB20 at full load conditions even that of diesel fuel. This is due to excess of oxygen content are present in biodiesel and lower viscosity and density of fuel.
5. The friction power was decreased at no load condition for all blends and increased by full load condition. the frication power was maximum for AB30 at full load conditions

Therefore it can be concluded that the argemone biodiesel blend AB20 (biodiesel 20%+80% diesel by volume) has improved fuel properties for diesel engine and improved performance.

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