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Properties investigation and performance analysis of a diesel engine fuelled with Jatropha, Soybean, Palm and Cottonseed biodiesel using Ethanol as an additive.*

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Abstract

Biodiesel is world widely recognized as an alternative fuel to conventional diesel fuel in compression ignition engines. It has many advantages including reduction of exhaust gases emissions such as CO, SOx, NOx, and hydrocarbon, higher cetane number, reduced toxicity, safety, and improved CO_2 lifecycle. But the poor cold flow properties and higher viscosity of biodiesel limits there usage in the field of transportation sector. Biodiesel derived from different raw feedstock of plant based oils or animal fats contained a significant amount of saturated free fatty acids which increases viscosity, cloud point and pour point of biodiesel. These properties can be enhanced by adding an ethanol as an additive in the blends of biodiesel with diesel which can be further able to enhance the engine performance and reduce harmful exhaust emissions. In the present experimental investigation, an ethanol is added to Jatropha, Soybean, Palm, and Cottonseed biodiesel with diesel as an additive by 5% volume. Properties are investigated as per IS 1448 standards. Investigation reported that addition of ethanol as an additive reduces the kinematic viscosity, cloud point and pour point of blends of biodiesel. The test fuels B20E5 (20% biodiesel + 75% diesel + 5% ethanol) of Jatropha , Soybean , Palm , and Cottonseed biodiesel are tested on single cylinder ,four stroke ,VCR (Variable Compression Ratio) electric start diesel engine connected to eddy current dynamometer for various load conditions to evaluate performance analysis of the engine. The performance analysis of investigation shows that there is an improved BP (Brake Power), increased BSFC (Brake Specific Fuel Consumption) and increased BTE (Brake Thermal Efficiency) for various loads on engine for Jatropha, Soybean, Palm and Cottonseed biodiesel- diesel blend with ethanol as an additive.

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Keywords: Biodiesel, Properties, Performance, Cloud Point, Pour Point.

Nomenclature

HC	Hydrocarban
CO	Carbon monoxide
SOx	Oxides of Sulphur
NOx	Oxides of Nitrogen
CO_2	Carbon Dioxide
IS	Indian Standards
BP	Brake Power
BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
P20	Palm oil biodiesel 20% + Diesel 80%
P40	Palm oil biodiesel 40% + Diesel 60%
P60	Palm oil biodiesel 60% + Diesel 40%
P80	Palm oil biodiesel 80% + Diesel 20%
P20E5	Palm oil biodiesel 20% + Diesel 75% + Ethanol 5%
P40E5	Palm oil biodiesel 40% + Diesel 55% + Ethanol 5%
P60E5	Palm oil biodiesel 60% + Diesel 35% + Ethanol 5%
P80E5	Palm oil biodiesel 80% + Diesel 15% + Ethanol 5%
COT20	Cottonseed oil biodiesel 20% + Diesel 80%
COT40	Cottonseed oil biodiesel 40% + Diesel 60%
COT60	Cottonseed oil biodiesel 60% + Diesel 40%
COT80	Cottonseed oil biodiesel 80% + Diesel 20%
COT20E5	Cottonseed oil biodiesel 20% + Diesel 75% + Ethanol 5%
COT40E5	Cottonseed oil biodiesel 40% + Diesel 55% + Ethanol 5%
COT60E5	Cottonseed oil biodiesel 60% + Diesel 35% + Ethanol 5%
COT80E5	Cottonseed oil biodiesel 80% + Diesel 15% + Ethanol 5%
S20	Soybean oil biodiesel 20% + Diesel 80%
S40	Soybean oil biodiesel 40% + Diesel 60%
S60	Soybean oil biodiesel 60% + Diesel 40%
S80	Soybean oil biodiesel 80% + Diesel 20%
S20E5	Soybean oil biodiesel 20% + Diesel 75% + Ethanol 5%
S40E5	Soybean oil biodiesel 40% + Diesel 55% + Ethanol 5%
S60E5	Soybean oil biodiesel 60% + Diesel 35% + Ethanol 5%
S80E5	Soybean oil biodiesel 80% + Diesel 15% + Ethanol 5%
J20	Jatropha oil biodiesel 20% + Diesel 80%
J40	Jatropha oil biodiesel 40% + Diesel 60%
J60	Jatropha oil biodiesel 60% + Diesel 40%
J80	Jatropha oil biodiesel 80% + Diesel 20%
J20E5	Jatropha oil biodiesel 20% + Diesel 75% + Ethanol 5%
J40E5	Jatropha oil biodiesel 40% + Diesel 55% + Ethanol 5%
J60E5	Jatropha oil biodiesel 60% + Diesel 35% + Ethanol 5%
J80E5	Jatropha oil biodiesel 80% + Diesel 15% + Ethanol 5%
D	Diesel

1. Introduction

The increasing demands of fuel in automobile sector and in power sectors combined with limited availability of conventional fuels and harmful ecological and environmental effects from their usage attracted many scientists and researchers towards developing different types of alternative fuels to replace the petroleum and diesel fuels. In the journey of finding new alternative fuels biodiesel has received good attention due to their complete CO2 lifecycle. Biodiesel is completely renewable fuels and reduces the harmful emissions from the engine such as CO, SOx and HC. But on the other side a major problems limits the use of biodiesel are higher viscosities, lower calorific values, increased brake specific fuel consumption, and poor cold flow properties such as cloud point, pour point and cold filter plugging point [1]. The harmful NOx emission also increases at higher blends of biodiesel. To address these difficulties an ethanol as an additive was added in biodiesel/diesel blend and properties, performance and emission analysis done by many researchers and scientist in last one decade. H.G. How et al. [2] experimentally investigated the effect of using ethanol as an additive in coconut biodiesel/diesel blends and reported that there is a higher brake specific fuel consumption and, higher thermal efficiency. The blends of ethanol, biodiesel and diesel showed the reduction in CO and NOx emissions compared to conventional diesel fuel. Fernando et al.[3] studied the ethanol biodiesel and diesel blend as an alternative to the conventional fuel. They reported that the blend of ethanol biodiesel and diesel blends showed the superior hot flow and cold flow properties than the conventional biodiesel and diesel blends. Barabas et al.[4] studied the fuel properties of ethanol and biodiesel blends and concluded that ethanol with 5% in volume in blend exhibits very good performance and emission characteristics as compared to conventional diesel fuels. Sayin et al [5] studied the single cylinder diesel engine with ethanol-diesel blend and methanol-diesel blend as a fuel. The results of investigation concluded that the CO,HC and brake thermal efficiency decreased , but BSFC (brake specific fuel consumption) and NOx exhaust emissions were increased for both the type of blends of biodiesel with ethanol and methanol. Zhu et al. [6] conducted trials on diesel engine fuelled with ethanol biodiesel blends. The investigation reported that BTE (brake thermal efficiency) increased and NOx and PM exhaust emissions were decreased. Further paper concludes that increasing ethanol percentage in higher blends of biodiesel increases the BSFC, HC and CO. R.D. Mishra et al. [7] reviewed the blending of different additives with biodiesel in order to improve performance, combustion emission and cold flow properties in a compression ignition engines.

In the present experimental investigation, an ethanol is added to different feedstock of biodiesel such as Jatropha, Soybean, Palm, and Cottonseed biodiesel with diesel as an additive by 5% volume. All properties such as viscosity, density, calorific value, flash point , fire point , cloud point and pour point of blends of biodiesel/diesel with ethanol are investigated as per IS 1448 standards. Investigation reported that addition of ethanol as an additive reduces the kinematic viscosity, cloud point and pour point of blends of biodiesel. The test fuels B20E5 (20% biodiesel + 75% diesel + 5% ethanol) of Jatropha , Soybean , Palm , and Cottonseed biodiesel are tested on single cylinder ,four stroke ,VCR (Variable Compression Ratio) electric start diesel engine connected to eddy current dynamometer for various load conditions to evaluate performance analysis of the engine.

2. Materials and Method

Different feedstocks of biodiesel such as Jatropha, Palm, Soybean, and Cottonseed were collected from SVM Agra Industries, Nagpur. An additive as an ethanol was collected from Aishwarya Chemicals, Pune. The conventional diesel fuel was collected locally. The blends were prepared in blending ratio of 20%, 40%, 60% and 80% biodiesel with diesel fuel without ethanol and 25%, 45%, 65% and 85% biodiesel with addition of 5% ethanol in diesel fuel. All the biodiesel/diesel fuel blend without ethanol and biodiesel /diesel fuel blend with ethanol were prepared on the basis of volume. Major physical and thermal properties such as density , calorific value, kinematic viscosity, cloud point, pour point, flash point, and fire point were investigated as per IS: 1448 standards for all types blends of biodiesel with ethanol and without ethanol . The investigated properties of blends of biodiesel with ethanol were compared with conventional diesel fuel and with blends of biodiesel without ethanol. Table 1 shows the properties of ethanol. Table 2 lists the various IS 1448 standards used for the measurement of various properties of biodiesel/diesel blends.

Table 1 Properties of Ethanol

Properties	Values
Kinematic Viscosity @ 20°C (cSt)	1.15
Density (kg/m^3)	789
Calorific Value (kJ/g)	27.32
Cetane Number	5-7

Table 2 IS 1448 Standards used for Measurement of fuel properties

Properties	IS 1448 Standards
Calorific value (kJ/kg)	Bomb Calorimeter
Kinematic Viscosity (cSt) @ 40°C	IS 1448 (Part I) (P-25)
Density (kg/m^3) @ 15°C	IS 1448 (Part I) (P-16)
Cloud Point in (°C)	IS 1448 (Part I) (P-10)
Pour Point (°C)	IS 1448 (Part I) (P-10)
Flash Point (°C)	IS 1448 (P-20)
Fire Point (°C)	IS 1448 (P-69)

3. Fuel properties findings and discussions

Smooth operation of a compression ignition engine depends on a various fuel properties. When additive an ethanol is added to the conventional diesel fuel and biodiesel some of the fuel properties used to get changed such as density, calorific value, kinematic viscosity cloud point, pour point, flash point, and fire point of the blend. Table 3 shows the investigation outcomes for the physical properties of blends of biodiesel without ethanol and with ethanol.

Table 3 Properties of various blends of biodiesel/ diesel blend without ethanol and with ethanol

Biodiesel Blend	Density (kg/m^3) @ 15°C	Calorific Value (kJ/kg)	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Fire point (°C)	Kinematic Viscosity (cSt) @ 40°C
P20	855	43595	-5	-7	28	44	2.9
P40	857	43483	1	-5	30	48	3.4
P60	860	42590	6	1	32	52	3.9
P80	887	41706	12	6	42	98	4.8
P20E5	846	40840	-8	-10	18	24	2.8
P40E5	850	40299	-3	-6	20	32	3.2
P60E5	854	39229	5	1	22	40	3.6
P80E5	876	37025	8	3	26	40	4.4
COT20	853	43221	-22	-18	30	42	2.8
COT40	865	42298	-21	-18	32	50	2.8
COT60	878	40911	-19	-16	32	55	5.3
COT80	891	39658	-18	-15	36	62	5.9
COT20E5	843	39761	-24	-20	14	20	2.6
COT40E5	850	38175	-21	-18	16	20	2.8
COT60E5	858	36192	-20	-17	26	38	4.3
COT80E5	886	35777	-19	-16	26	40	5.16
J20	830	43320	-4	-7	-	-	3.17
J40	847	43300	-3	-5	-	-	3.25
J60	850	42890	-3	-3	-	-	3.65
J80	859	42345	-2	-3	-	-	4.5
J20E5	825	43200	-8	-9	-	-	2.5

J40 E5	840	43189	-5	-7	-	-	2.9
J60 E5	847	42567	-4	-5	-	-	3
J80 E5	855	41876	-3	-4	-	-	4.25
S20	823	43500	-3	-6	-	-	2.95
S40	831	40851	-2	-5	-	-	3.28
S60	855	40556	-2	-4	-	-	3.82
S80	857	40299	-1	-3	-	-	4.36
S20 E5	820	40298	-6	-8	-	-	2.5
S40 E5	825	39791	-3	-6	-	-	2.8
S60 E5	850	39210	-3	-5	-	-	-
S80 E5	853	38985	-2	-3	-	-	-
Diesel	817	43851	-23	-21	40	42	2.5

Fig 1. Shows the variation of density of biodiesel with blend ratio for different feedstock of biodiesel with and without ethanol. Density of the fuel is most important property of biodiesel fuel. Other fuel properties such as viscosity, calorific value are also associated with this property. Density of ethanol is less than the diesel. So addition of ethanol decreases the density of biodiesel blends for all proportions.

Fig 2. Shows the variation of calorific value of biodiesel with blend ratio for different feedstock of biodiesel with and without ethanol. Calorific value of biodiesel blends is another very important characteristic. Lower heating value of biodiesel blend influences the overall power output from the engine. The calorific value of ethanol and biodiesel is less than the conventional diesel fuel. So addition of ethanol in the biodiesel diesel blend reduces the calorific value of the entire blends for all the feedstock of biodiesel for all blend ratios.

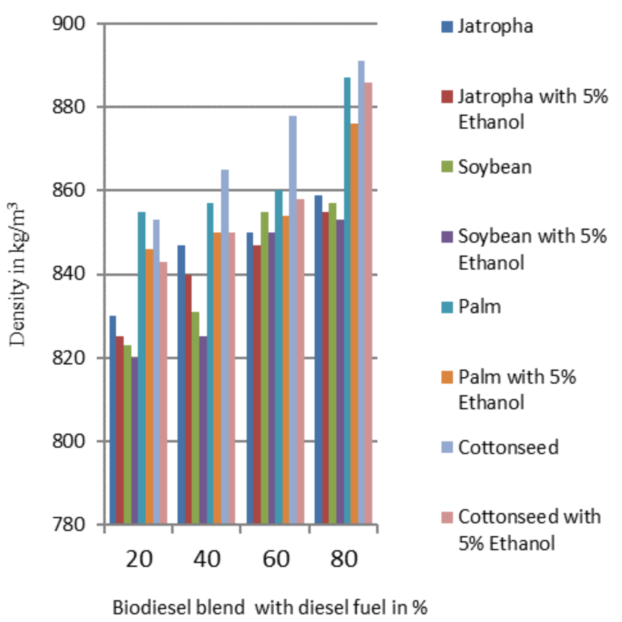

Fig 1.Variation of Density of biodiesel with blend ratio

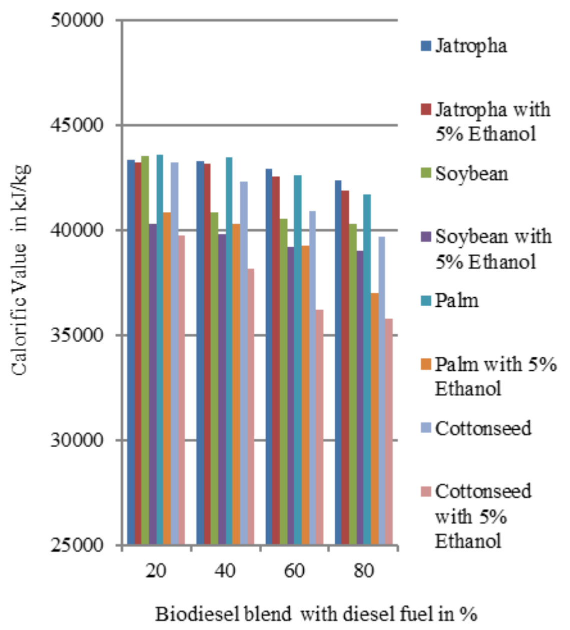

Fig 2. Variation of Calorific Value of Biodiesel with blend ratios

Fig 3 and Fig 4 shows the variation of cloud point and pour point with blend ratio for different feedstock of biodiesel with and without ethanol. Generally the cloud point and pour point of biodiesel is higher than conventional diesel fuel. But the cloud point and pour point of ethanol is very low as compared to biodiesel. Due to very low cloud point and pour point of ethanol, its addition to the biodiesel /diesel blend decreases the cloud point and pour point of the final blend for all the feedstock of biodiesel/diesel.

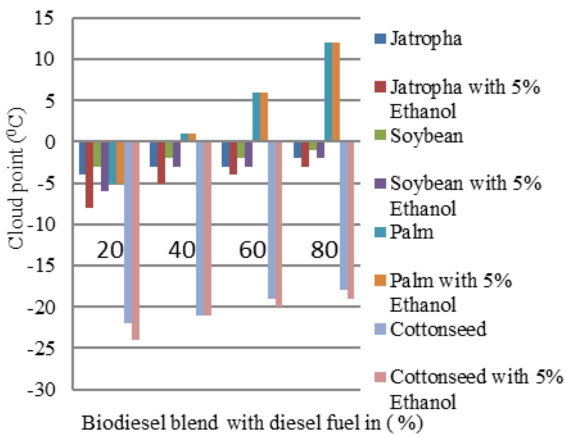

Fig 3 Variation of cloud point with % blend of biodiesel

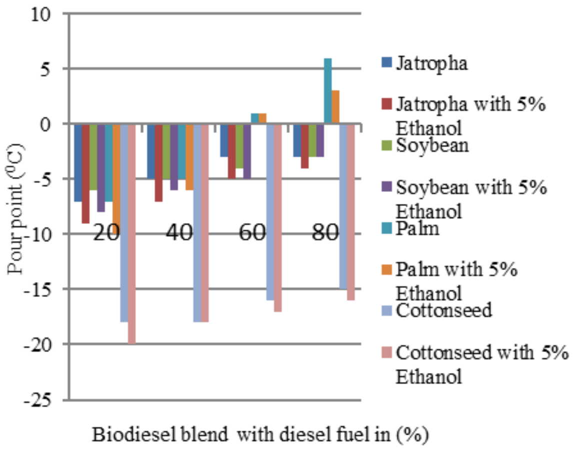

Fig 4 Variation of pour point with % blend of biodiesel with diesel.

4. Test Fuel and Experimental Set up

4.1. Test fuel

Test fuels used for the experimentation on engine trials were Diesel, 20% blend of biodiesel of Jatropha, Palm, Soybean, and cottonseed with 80% of diesel by volume. These blends are denoted by D, J20, S20, P20, COT20 respectively. Also the ethanol was added in 5% by volume in the blend and 5% volume of diesel was reduced in every blend so that diesel percentage in every blend was only for 75% by volume . These blends are denoted by J20E5, S20E5, P20E5 and COT20E5.

4.2. Experimental Set up

The engine setup consists of four stroke, single cylinder, variable compression ratio (VCR) diesel engine. Engine was connected to eddy current dynamometer for varying loads on the engine. The compression ratio of the engine was set to be 18. Engine set was equipped with essential instruments for crank angle and cylinder pressure measurements. Signals were interfaced to data logger to computer for P-θ and for P-V diagrams. Airflow, fuel flow, temperatures and load measurement were interfaced with computer. The set up was equipped with a panel box consisting of air box, fuel tanks for blend test, U-tube manometer, fuel measuring system, transmitters for air and fuel flow measurements. For cooling water and calorimeter water flow measurement, rotameters were provided. Test were carried out on experimental fuel for varying load conditions of zero load, 3kg load, 6kg load, 9kg load, and 12kg load at 1500 constant rpm. The trials were studied for engine performance for brake power, indicated power, frictional power, brake mean effective pressure, indicated mean effective pressure, , brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Labview based engine performance analysis software, Engine soft was provided for real time performance evaluation.

5. Result and discussion

5.1. Brake Power

Fig 5 shows the variation of brake power with load. As the part of oxygenated compounds of biodiesel and ethanol in the blend with diesel increases, the brake power of the biodiesel/diesel blend and biodiesel/diesel with ethanol blend reduces than the conventional diesel fuel for all the variable loads. Lower cetane number and lower calorific value of the biodiesel and ethanol are the important factors to reduce the brake power of the blend. Investigation reported that for J20E5 brake power reduces from 3 to 6%, for S20E5 from 5 to 12 %, for P20E5 from 7 to 8% and for COT20E5 reduces from 6 to 7 % as compared to conventional diesel fuel at all load conditions.

5.2. Brake Specific Fuel Consumption

Fig 6 shows the variation of brake specific fuel consumption with load. As the calorific value or the energy content of the blend decreases, the BSFC increases as compared to conventional diesel fuel. Because of low calorific value of the biodiesel/diesel - ethanol blends, increases the BSFC. Investigation reported that for J20E5 BSFC increases from 2 to 9%, for S20E5 from 1.5 to 2.5 %, for P20E5 from 1 to 7% and for COT20E5 increases from 2 to 9 % as compared to conventional diesel fuel at all load conditions. BSFC is dependent on the constitutes of the fuel i.e portion of biodiesel and ethanol in the blend. When the biodiesel ethanol contents increases in the blend, the BSFC also increases.

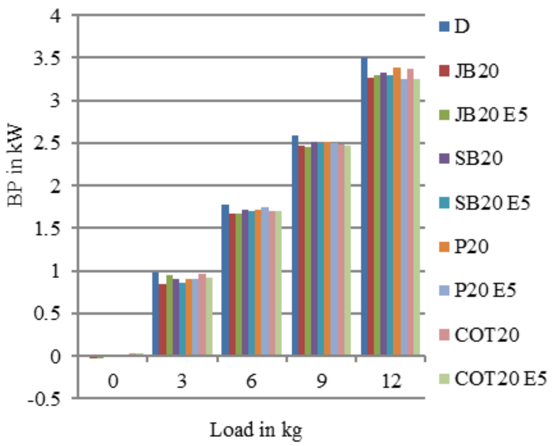

Fig 5 Variation of BP with Load

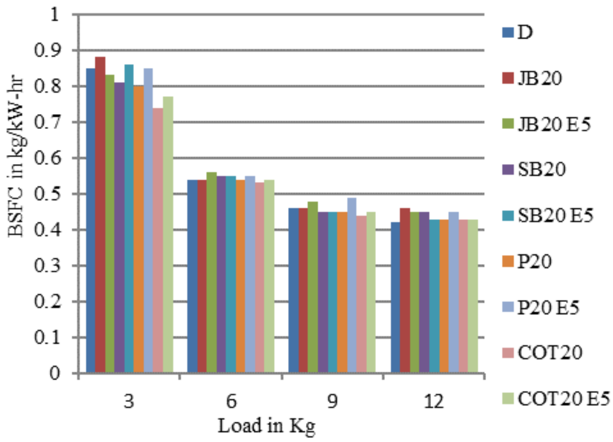

Fig 6 Variation of BSFC with load

5.3. Brake Thermal Efficiency

Fig 7 shows the variation of brake thermal efficiency with load. Investigation reported that for diesel- biodiesel-ethanol blends, brake thermal efficiency is increases than the biodiesel-diesel blend at all load conditions. This is because of higher oxygen content in the blend which leads to maximum combustion of blends in the combustion chamber. So brake thermal efficiency increases as the ethanol in the blend increases. It is found that for J20E5 BTE increases from 5 to 9%, for S20E5 from 3 to 9 %, for P20E5 from 4 to 7% and for COT20E5 increases from 1 to 2 % as compared to biodiesel-diesel fuel blend without ethanol at all load conditions. BTE of diesel fuel is highest than the biodiesel/diesel blend without ethanol and with ethanol fuel at all engine load conditions.

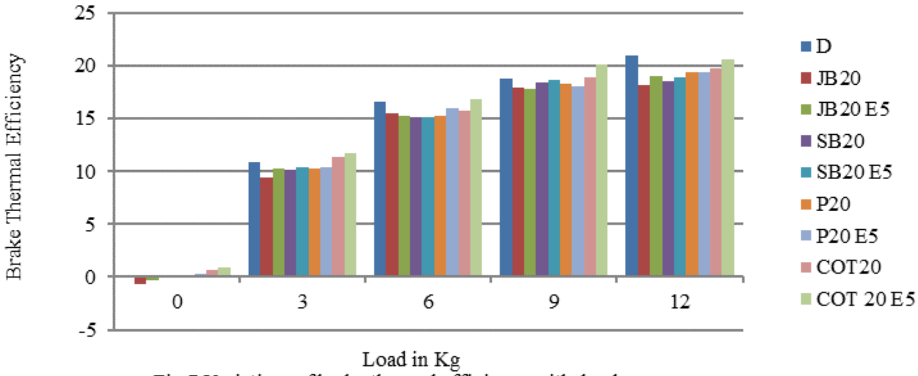

Fig 7 Variation of brake thermal efficiency with load

6. Conclusions

To prepare a blend of biodiesel-diesel fuel with ethanol as an additive, an ethanol with a concentration of 99% should be used and amount of ethanol should be kept as low as possible up to only 5% by volume in the total blend ratio. During properties investigation many trials were carried out as per IS 1448 standards on the different blends of biodiesel such as Jatropha, Palm, Soybean and cottonseed with diesel and ethanol. According to the experimental results addition of ethanol decreases the density of all biodiesel diesel ethanol blends also the heat content or calorific value of the blend decreases by addition of ethanol. But on the other side the kinematic viscosities decreases for all the blends of biodiesel/diesel with ethanol which improves the spray pattern of the fuel in the cylinder and enhanced the quality of combustion. Cold flow properties such as cloud point and pour point of biodiesel diesel and ethanol blend improves drastically by addition of ethanol in the blend. This will increases the usability of biodiesel in cold conditions. The performance analysis of investigation shows that there is an improved BP (brake power), increased BSFC (brake specific fuel consumption) and increased BTE (brake thermal efficiency) for various loads on engine for Jatropha, Soybean, Palm and cottonseed biodiesel- diesel blend with ethanol as an additive.

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