INVESTIGATION OF COTTONSEED OIL BIODIESEL WITH ETHANOL AS AN ADDITIVE ON FUEL PROPERTIES, ENGINE PERFORMANCE, COMBUSTION AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE

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In last few years in automobile sector there is a emerging need of an alternative fuel because of depletion of the stock of fossil fuels in all over the world. Biodiesel in this regard contested a strong alternative to the conventional fuels. Biodiesel contains 9 to 10% higher oxygen and higher cetane number which allows its good combustion in the combustion chambers of the engine. But poor hot flow and cold flow properties of biodiesel restricts their applications in the field of automotives. So the blends of biodiesel in percentage with diesel and ethanol as an properties enhancer additives are used in the biodiesel/diesel blend. Reduced viscosity, higher calorific value, improved flash and fire point and enhanced cold flow properties of the blends with ethanol as an additive, enhanced the combustion and reduced harmful emissions from the engine. Experimental work presented in this paper is by considering cottonseed biodiesel as raw feedstock blended with diesel and 5% ethanol. Properties were investigated experimentally as per IS 1448 standards. Trials were conducted on the single cylinder diesel. Results show that there are significant improvements in the properties of the blend, performance, combustion and reduced harmful emission from the engine. Experimental investigation reported that ethanol as an additives in the blends of cottonseed biodiesel with diesel reduces kinematic viscosity by 7% , cold flow properties by 9% to 10% . But on the other hand but density of the blend is increased by 3% and higher heating value is decreased by 9%.

Keywords: *cottonseed, biodiesel, ethanol, emissions, performance, engine*

Introduction

The depletion of fossil fuel reserves, demands the need of alternative fuels in the field of energy, power and transportation sector. Bio origin based fuels are able to fill the gap of depletion of petroleum based fuels and their demand in the various sectors [1]. Diesel operated transport vehicles are the major contributor in the environmental harmful emission. Various types of bio energy based fuels are experimented and tested by the researcher and scientists worldwide such as biogas, biomass, alcohols, vegetable oils and biodiesel etc. All these bio friendly resources are environment protective and economic in their usage and application, but on the other hand primarily they required to processed and convert it in to the useful form as per the need or application [2]. As compared to all other bio energy based fuels, biodiesel contested its strong stand and leaves a remarkable foot prints in the field of alternative fuels. Petroleum products are absent in the biodiesel, and can be blended in the conventional diesel in order to form biodiesel blends [3]. Blending of biodiesel is possible in terms of percentage with diesel and can be identified as B20, B40, and B60 and so on. Where 'B' stands for biodiesel and corresponding number indicates its percentage in the overall blend [4]. In this present study cottonseed oil is used as raw a feedstock for making of biodiesel. Transesterification process is required to convert the raw cottonseed oil in to the biodiesel. Biodiesel is known for its biodegradability, sulphur free content and for its non toxicity [5]. In the transesterification process oil reacts with an alcohol and forms esters of oil and glycerol. In order to increase the rate of reaction a catalyst is used in the process. The hot flow properties of the biodiesel are changed because of transesterification process, such as viscosity of cottonseed oil biodiesel which reduces significantly as compared to viscosity of raw cottonseed oil [6]. But on the other hand high density, high cloud point and pour point and also most importantly low calorific value as compared to conventional fuel. All these properties affect the engine performance, combustion and emissions from the engines [7]. This requires adding certain additives in the blends of biodiesel with diesel in order to improve these properties. In the present study Ethanol is identified as an additive and blended in the blends of biodiesel by which these properties are improved [8].

Ethanol [CH_3CH_2OH] is also known as Ethyl alcohol. Ethanol is having a higher octane number which plays a very important role in the combustion of fuel in the internal combustion engines. It also contains higher percentage of oxygen by 34% which is significantly more than conventional fuel. Higher oxygen helps to improve combustion characteristics of the engines [9].Fermentation is process by which ethanol is prepared [10]. Table 1 shows the basic properties of 99.99% ethanol, which is tested as per IS 1448 standards in the NABL accredited laboratory.

Table: 1 Properties of 99.99% pure ethanol [9-10]

Properties	Ethanol
Cetane number	8
Density (kg/m³)	790
Cloud point°C	<-26
Calorific value (MJ/Kg)	26.95
Flash point °C	13
Viscosity (Cst)	1.4

Test fuel and properties investigation:-

Cottonseed oil is extracted from the cotton plant. Transterification is the process by which the cottonseed oil is converted in to cottonseed oil biodiesel [11]. As compared to the other edible and non edible vegetable oil, properties of cottonseed oil biodiesel are found to be very compromising and attract the attention of many researcher and scientists to consider him as an alternative fuel for diesel engine. But lower heating value, higher viscosity and density of cottonseed oil biodiesel restricts its application in the engine as a a pure biodiesel fuel [12]. So the fuel blends are prepared on volumetric basis with diesel fuel. Also ethanol is added by 5% in the blend in order to decrease the overall viscosity of the blend [13]. All the thermo-physical properties of the blends are tested as per the IS 1448 standards in NABL accredited laboratory. Table 2 shows the thermo-physical properties of 100 % biodiesel and table 3 shows the properties of blends of cottonseed biodiesel with and without ethanol.

Table 2: Properties of 100% pure Cottonseed oil Biodiesel

Sr. No.	Test Parameters of Pure cottonseed oil biodiesel	Units	Results	Test Standards
1	Kinematic Viscosity@40^0 C	cSt	7.5	IS 1448 (Part I) (P-25)
2	Density	kg/m^3	904.8	IS 1448 (Part I) (P-16)
3	Fire Point	^{0}C	190	IS 1448 (P-20)
4	Pour Point	^{0} C	-15	IS 1448 (Part I) (P-10)
5	Cloud Point	^{0} C	-17	IS 1448 (Part I) (P-10)
6	Flash Point	^{0}C	142	IS 1448 (P-69)
7	Calorific Value	kJ/kg	36802	IS 1448 Bomb Calorimeter

Table: 3 Thermo-physical properties of Cottonseed oil biodiesel/diesel blends with and without ethanol.

Fuel	Calorific Value kJ/kg	Kinematic viscosity cSt	Cloud point °C	Pour point °C	Density Kg/m^3
C100	36802	7.5	-17	-15	904.8
Diesel	43851	2.5	-23	-21	817.4
C20D80	43221	2.8	-22	-18	850.1
C40D60	42298	2.8	-21	-18	865.6
C60D40	40911	5.3	-19	-16	878.1
C80D20	39658	5.9	-18	-15	891.5
C20D75E5	39761	2.6	-24	-20	842.9

C40D55E5	38175	2.8	-21	-18	850.6
C60D35E5	36192	4.3	-20	-17	858.1

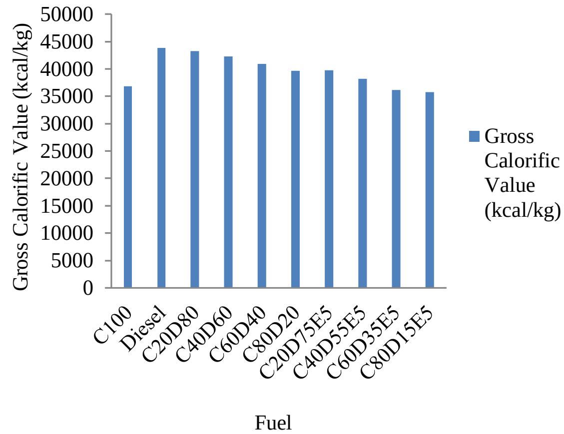

Fig 1 Effect of percentage blend of cottonseed oil biodiesel with and without ethanol on Calorific Value.

Fig 1 shows effect of percentage blend of cottonseed oil biodiesel with and without ethanol on Calorific Value. Heat release is the most important property of the any fuel and is determined by the calorific value [14-16]. Lower calorific value of cottonseed oil biodiesel and ethanol reduces the total calorific value of the overall blends. As compared to conventional diesel for C20D75E5 calorific value was lowered by 9% with ethanol as an additives and for C20D80 i.e cottonseed oil biodiesel without ethanol, it is decreased by 2% as compared to conventional diesel. The same results and trend lines are observed for other cottonseed oil biodiesel blends with and without ethanol. So it is concluded that as the percentage of cottonseed oil biodiesel increases in the diesel, the calorific value of the blends decreases.

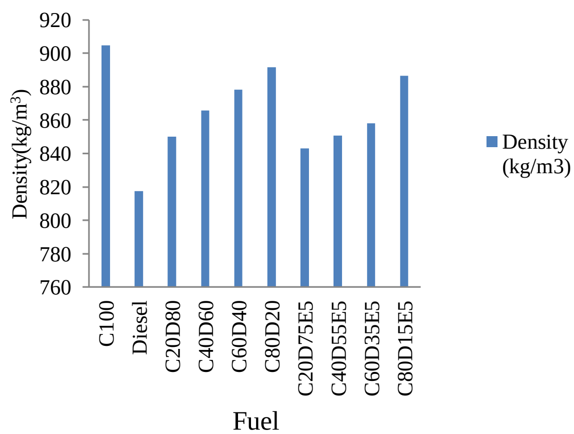

Fig 2 Effect of percentage blend of cottonseed oil biodiesel with and without ethanol on density.

Fig 2 shows the effect of percentage blend of cottonseed oil biodiesel with and without ethanol on density. As ethanol is having lower density as compared to diesel and biodiesel, it affects the total density of the blends [17-19]. It is recorded that for C20D75E5 density is 3% greater than the conventional diesel but at the same time it is less than C20D80 by 1%. Lower density of the blends obliviously lowers the occupancy of the fuel in the combustion chamber, which ultimately affect the combustion and emissions from the engines. For all other blends similar results are recorded.

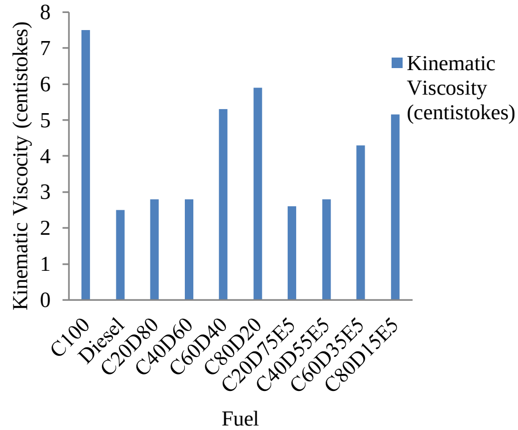

Fig 3 Effect of percentage blend of cottonseed oil biodiesel with and without ethanol on kinematic viscosity

Fig 3 shows effect of percentage blend of cottonseed oil biodiesel with and without ethanol on kinematic viscosity. Maximum atomization of the fuel is only possible with lower viscosity of the fuel in the combustion chamber and with maximum atomization the maximum combustion pressure and temperature able to build on the head of the piston [20-22]. As ethanol is having the lower viscosity and when it is added in the blends of cottonseed oil biodiesel it decreases the overall viscosity of the blends. It is recorded that for cottonseed oil with ethanol i.e, C20D75E5 the viscosity reduces by 7% as compared with the cottonseed oil blends without ethanol C20D80. Similar readings are recorded for other blends ratio of cottonseed oil biodiesel with and without ethanol.

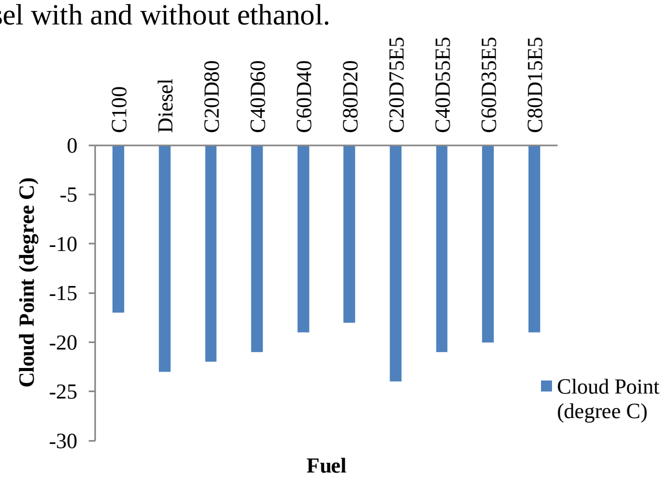

Fig 4 Effect of percentage blend of cottonseed oil biodiesel with and without ethanol on Cloud point

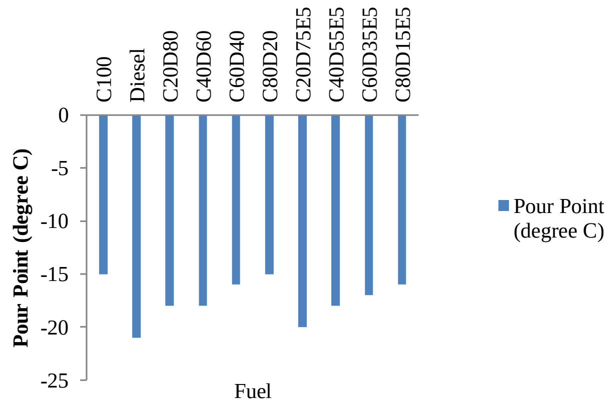

Fig 5 Effect of percentage blend of cottonseed oil biodiesel with and without ethanol on Pour point

Fig 4 and fig 5 shows effect of percentage blend of cottonseed oil biodiesel with and without ethanol on Cloud point and on Pour point. Cold flow properties of blends of biodiesel such as cloud point and pour point plays very important role in the usability of biodiesel in cold weather conditions. Biodiesel generally has higher cloud point and pour point, as ethanol is added in the cottonseed oil biodiesel blend, it is recorded that cloud point increases for C20D75E5 by 9% than C20D80. Similarly the pour point of C20D75E5 increases by 10% than the C20D80.

Experimental set up and test fuel

The two different blends of cottonseed oil biodiesel with and without ethanol were prepared and tested on test engine. The different blends consist of 20 % cottonseed oil biodiesel with 75 % diesel and ethanol was added for 5% i.e C20D75E5, and the same blend was prepared without ethanol i.e C20D80 in order to test the effect of ethanol on the performance, combustion and emission parameters of an engine. Variable compression engine was selected for test of having 18 compression ratios. The engine was four strokes, single cylinder equipped with eddy current dynamometer. Engine test rig was readily equipped with different transducer and sensor such as pressure transducer, crank angle sensor etc. Data logger with Lab view software was interfaced with computer in order to record real time data of engine trials. Air box was used in order to measure air consumption. For measurement of fuel consumption U –tube manometer and fuel measuring systems were used. Engine was also mounted with K-type and PT 100 type thermocouples in order to record various engine temperatures. Trials on the engine were performed first by considering no load conditions on the engine i.e 0kg with diesel fuel and cottonseed oil biodiesel with and without ethanol as a fuel .Once the engine was tuned to the system then,with the help of eddy current dynamometer the load on the engine was varied in the range of 3kg, 6kg 9kg and 12 kg at constant 1500 revolution per minute.

Result and discussion

1. Performance Analysis

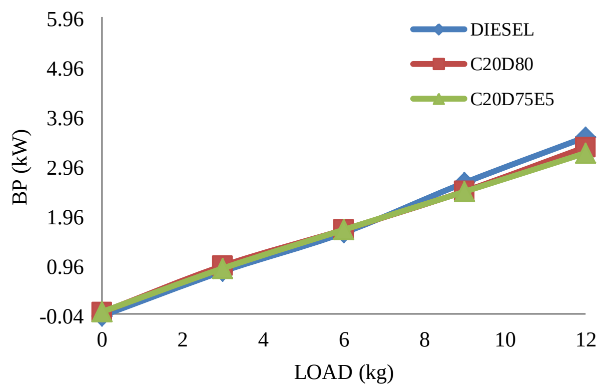

Fig 6 Effect of engine load on Brake Power

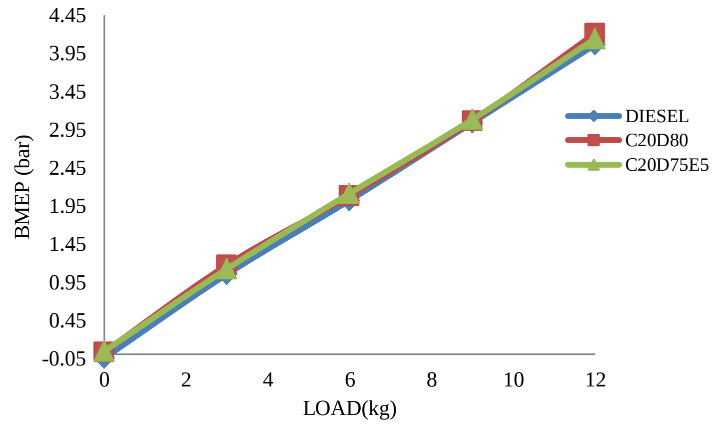

Fig 7 Effect of engine load on the brake mean effective pressure.

Fig 6 shows effect of varying engine load on the brake power. At no load conditions there were not significant variation in the brake power output when engine turned on cottonseed oil biodiesel with and without ethanol as a fuel. Because of the lower calorific value of C20D75E5 as compared with C20D80 the brake power of cottonseed oil biodiesel with ethanol was reduced 8 to 9% as compared with conventional diesel. Fig 7 shows the effect of engine load on the brake mean effective pressure. As there is no significant variation in the brake power at no load conditions, that means piston head used to experience a same brake mean effective pressure during the cycle when engine turned on cottonseed oil biodiesel with and without ethanol as a fuel. Low brake power and lower kinematic viscosity of C20D75E5, increases BMEP by 2 to 7% as compared with the C20D80 and diesel fuel.

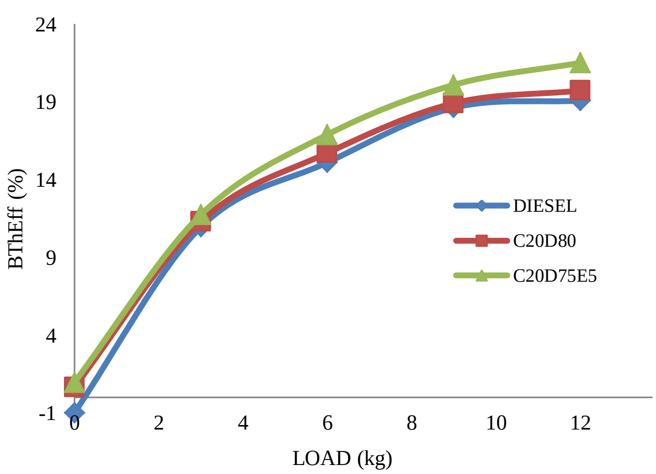

Fig 8 Effect of engine load on the Brake thermal efficiency

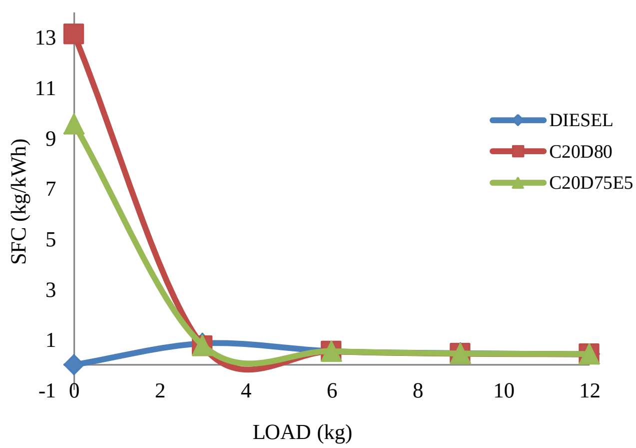

Fig 9 Effect of engine load on specific fuel consumption

Fig 8 shows the effect of engine load on the brake thermal efficiency. It is recorded that for cottonseed oil biodiesel with ethanol as an additive, the brake thermal efficiency was improved from 7 to 12% than the C20D80 and diesel fuel. This is because of increase brake mean effective pressure of C20D75E5 as compared withC20D80.Also lower kinematic viscosity of C20D75E5 also contributed lot in order to increase the brake thermal efficiency. Fig 9 shows effect of engine load on the specific fuel consumption. At no load condition the SFC (specific fuel consumption) of diesel fuel recorded lesser than cottonseed oil biodiesel with and without ethanol. SFC of the cottonseed oil with ethanol is less than SFC of the cottonseed oil without ethanol because biodiesel contains more oxygen as compared with diesel fuel, so specific fuel consumption of cottonseed oil biodiesel with ethanol and without ethanol increases 1 to 3 % as compared with conventional fuel.

Emission Analysis

The carbon dioxide, hydrocarbon, carbon monoxide and nitrogen oxides are the very harmful engine exhaust emission from the engine. Fig 10, Fig 11 Fig 12 and Fig 13 shows the variation of engine emissions of carbon monoxide, hydrocarbon, carbon dioxide and nitrogen oxide with engine load condition respectively. Experimental trials reported that for cottonseed oil biodiesel with ethanol as an additive C20D75E5, the emissions of carbon monoxide were higher than the conventional diesel but on the other hand they were reduced by 10 to 30 % as compared with cottonseed oil biodiesel without ethanol C20D80. At no load conditions i.e 0 kg load the carbon monoxide emissions for the diesel fuels were 6.7 % but on the other hand for the cottonseed oil biodiesel , it was recorded as 6.2%.Trials also reported that the hydrocarbon emissions of cottonseed oil biodiesel with ethanol blend C20D75E5 were higher than conventional diesel. But a different trend is observed for load of 3 kg for diesel as compared with biodiesel which needs to be investigate. At no load conditions the HC emissions of the cottonseed oil biodiesel without ethanol was higher than the cottonseed oil biodiesel with ethanol as additives. But for diesel the HC emissions are lower than cottonseed oil biodiesel with and without ethanol. At higher load condition it was observed that carbon dioxide emission were higher for cottonseed oil biodiesel with ethanol blend C20D75E5, by 4% to 20% as compared with cottonseed oil biodiesel without ethanol blend C20D80 . As biodiesel is known for more oxygen contains, NOx used to form at higher temperature. An experimental trials show that there is a reduction of NOx in cottonseed oil biodiesel with ethanol C20D75E5, by 8 % to 9% as compared to cottonseed oil biodiesel without ethanol C20D80.

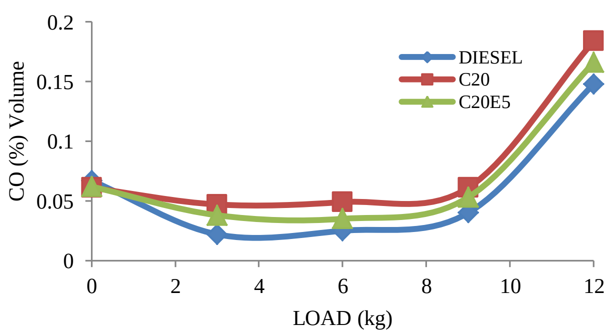

Fig 10 Carbon monoxide in (%) Volume with engine load

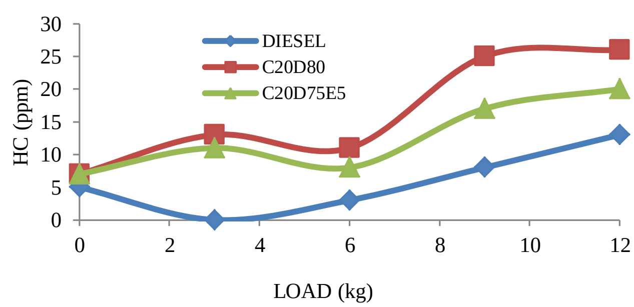

Fig 11 Hydrocarbon in ppm with engine load

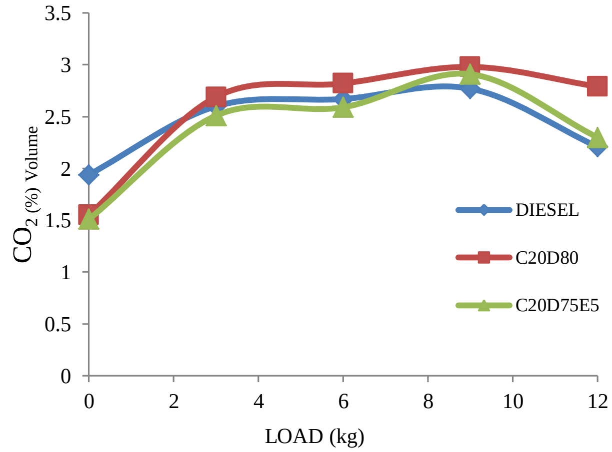

Fig 12 Carbon dioxide in (%) Volume with engine load

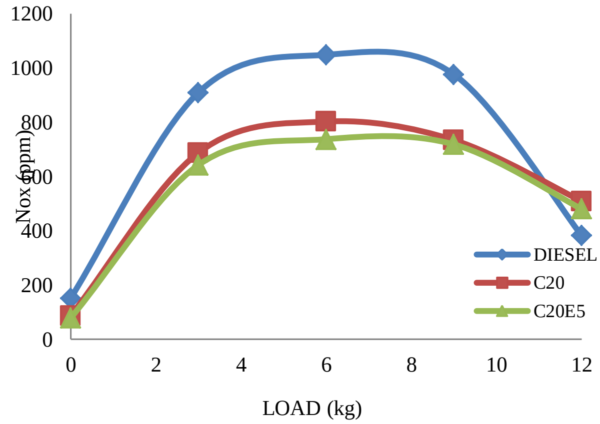

Fig 13 Nitrogen Oxide in ppm with engine load

Combustion Analysis

The cylinder pressure variation with crank angle is shown in fig.14. As diesel fuel is having a higher calorific value, low kinematic viscosity and density the maximum combustion of fuel happens in the combustion chamber which gives maximum build of pressure force on the head of the piston [23-24]. But this is not possible in case of cottonseed oil biodiesel without ethanol when it is used as a fuel in the cylinder. Addition of the ethanol in the cottonseed oil biodiesel blend decreases the kinematic viscosity, which ensures maximum burning of the fuel in the cylinder when it is injected in the cylinder because of this the cylinder pressure built by the combustion of cottonseed oil biodiesel with ethanol gives higher pressure on the head of the piston than cottonseed oil without ethanol when it is used in the cylinder as fuel.

Fig 15 shows the variation of mass fraction of fuel used at the time of injection with crank angle. Maximum fuel is injected as per valve time diagram of the engine i.e 10^0 before TDC and 20^0 after TDC. It is observed that more quantity of fuel required in cottonseed oil biodiesel without ethanol. This is because of higher viscosity and density of the fuel as compared with cottonseed oil biodiesel with ethanol. The mass fraction i.e quantities of fuel used in both the cases of cottonseed oil biodiesel with and without ethanol were higher than diesel.

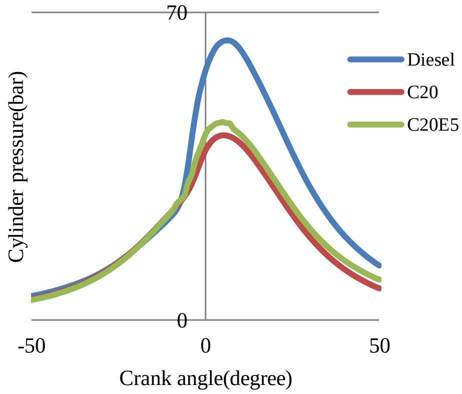

Fig 14 Variation of cylinder pressure with crank angle

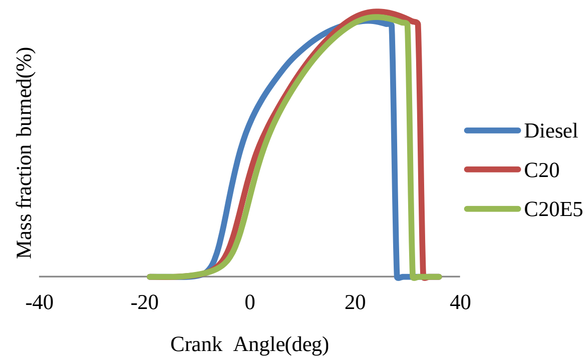

Fig 15 Variation of quantity of fuel as per crank angle

Conclusions

The thermo-physical properties of the cottonseed oil biodiesel –diesel with and without ethanol were investigated as per IS 1448 standards. An experimental investigation concludes that as far as possible addition of ethanol up to 5% in the blend on the basis of volume able to give formulation of desirable properties of the blend. Addition of ethanol as additive in cottonseed oil biodiesel –diesel blends enhances the kinematic viscosity by 7% as compared with the cottonseed oil biodiesel-diesel without ethanol. Lower kinematic viscosity improves good atomization and combustion in the engine cylinder. Also cold flow properties of cottonseed oil biodiesel-diesel with ethanol as an additive improves cloud point and pour point by 9% to 10% as compared with cottonseed oil biodiesel –diesel blend without ethanol. Increased cloud point and pour point extends the usability of biodiesel blend in the cold weather conditions. Experimental trials were conducted on single cylinder four stroke diesel engine equipped with eddy current dynamometer. Performance analysis shows that brake power of the engine when fuelled with cottonseed oil biodiesel –diesel blend with and without ethanol comparably same at high loads. But because of lower viscosity of the ethanol blend the brake mean effective pressure increases by 2%. Also the brake thermal efficiency in the cottonseed oil biodiesel with ethanol blend increases by 7% to 12% for varying load condition as compared with blend without ethanol. Emission analysis reported that for cottonseed oil biodiesel –diesel blend with ethanol , the emissions of carbon monoxide reduces by 10% to 30% ,emission of hydrocarbon reduces by 30% to 60%, emissions of carbon dioxide reduces by 4% to 6% as compared with cottonseed oil biodiesel –diesel blends without ethanol. At the same time nitrogen oxides emissions were also reduced for ethanol blend. So by and large it is concluded that ethanol as an additives in the cottonseed oil biodiesel-diesel blend improves properties of the fuel , performance of the engine, reduces the engine emissions and improves combustion of fuel in the engine and proves him a strong contestant as an alternative fuel.

Nomenclature

C100	- Cottonseed oil biodiesel 100 %
C20D80	- Cottonseed oil biodiesel 20 % + Diesel 80%
C40D60	- Cottonseed oil biodiesel 40 % + Diesel 60%
C60D40	- Cottonseed oil biodiesel 60 % + Diesel 40%
C80D20	- Cottonseed oil biodiesel 80 % + Diesel 20%
C20D75E5	- Cottonseed oil biodiesel 20 % + Diesel 75% + Ethanol 5%
C40D55E5	- Cottonseed oil biodiesel 40 % + Diesel 55% + Ethanol 5%
C60D35E5	- Cottonseed oil biodiesel 60 % + Diesel 35% + Ethanol 5%
ppm	- Parts per millennium
HC	- Hydrocarbon

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