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Effect of injection pressure on performance and emission of CRDIengine operated with biofuel produced from cashew nut sh ell liquid mixed with Honge methyl ester

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Abstract: In this research work, raw Cardanol, which is a biofuel based on a non edible plant, produced from cashew nut shell liquid(CNSL) was blended with Honge methyl ester (HME) used as a test fuel in a VCR CRDI diesel engine.Biofuel blends C5H10 (5 % Cardanol +10 % Honge methylester +85 % Diesel), C10H10,C15H10 and C20H10 were prepared and tested under varied load conditions at three different injection pressures(300 bar , 400 bar and 500bar) and compared to diesel fuel. It was found that when the injection pressure increased from 300 to 500 bar, the brake thermal efficiency improved from 30.53% to 31.93% for C10H10 compared to 32.54% for diesel with reduction in Carbon monoxide (CO) and unburned hydrocarbons but Nox levels and smoke opacity were observed to high. From this study it is shown that 500 bar injection pressure found optimum for C10H10 blend could improve the performance and emission in diesel engine.

Keywords: Cardanol, injection pressure, Honge methyl ester, emission, performance

I. Introduction

With increased industrialization and development in automotive sector, demand for excess use of petroleum products in the current world. The oil based reserves are limited and concentrated in certain parts of the world. Manycountries which do not have such resource are now facing a foreign exchange crisis, primarilydue to crude oil Imports[1]. With greater industrialization of the modern world is raising demand for petroleum due to environmental degradation caused by accumulation of green house and global warming due to emissions of pollutants from transport vehicles and industries. The use of fossil fuels not only causes environment al pollution abut also affects economic development. These problems can be solved by finding suitable replacement fuels for I.C. Engines. A lot of universal research shows that biodiesel can be used as a substitute for fossil fuels [2-5].Internal combustion engines are currently powered by fossil fuels and it is understand that the reserves of fossil fuels deplete at a rapid rate, fossil fuel burning leads to environmental issues like acid rain, smog ,global warming and depletion of ozone[6].

Biodiesel is one of these alternatives that is made from animal fats and vegetables and is renewable in nature [7].The method of trans esterification is used to generate biodiesel from vegetables and animal fats, They can be made from oils which are edible and non-edibles, use of edible oils for processing biodiesels can affect the food and non-edible oils are widely used in biodiesel production[8].Cardanol is one of India's readily available non-edible biofuel sources at a lower cost[9].Cardanol is a phenolic liquid produced by the cashew nut shell liquid (CNSL) distillation process, which is a byproducts of cashew industry [10].Many researcher have mixed cardanol with diesel in different percentage and found that good performance and thermal efficiency [11-12].The author concluded from the experimental investigation that upto 40% of PPME s blend offers better efficiency and reduced emissions [13].The Cardanol biofuel blends experiment are conducted in a dual cylinder CI Engines, The author found that up to 20 % of cardanol biofuel can be used in CI Engine without any modifications [14].The authors found that by combining 3 types of feed stock(Polonga,Crouch and Jatrophacurcus) and finding that physiochemical properties of biodiesel are greatly improved [15].The author researched raw cardanolblended with kerosene with three blends used as test fuels. They found that compression ratio increased from 16:1to 18:1, the brake thermal efficiency increased with decrease in carbon monoxide, unburned hydrocarbonsand good results were observed .But Nox emission was increased by 18.7,1.8 and 7.3% respectively[16].

So far, Cardanol has not been tested in diesel engines by blending with Honge methyl ester. In the present study raw Cardanol was blended with Honge methyl ester (HME) and tested in CRDI VCR diesel engine for different injection pressures(IP)such as 300 bar, 400 bar and 500 bar at 27 bTDC with18:1 compression ratio at 1500 rpm to investigate the performance and emission of cardanolhonge blends.

II. MATERIALS AND METHODOLOGY

In this current study raw Cardanol and Honge methyl ester (HME) blends were used as test fuel. Double distilled cardanol was purchased from cashew industry. Cardanol and HME blends C5H10 (5 percent Cardanol+10 percent HME+85percentDiesel), C10H10, C15H10 and C20H10 volume based blends were prepared. The caloric for each blend was measured using bomb calorimeter as per ASTM standard D240, Kinematic viscosity was measured using a Cannon –Fenske Viscometer as per ASTM D445 standard. The flash point was calculated as per ASTM D93 standard using PenskyMartens closed cup apparatus. The density of each blend was measured using hydrometer as per ASTM D4052.The properties of the test fuels are given in Table 5.

Experiments were carried out on single cylinder CRDI VCR diesel engine is shown in Fig.1.Cardanol ,HME blend with diesel is used as a fuel to conducted experiment to test the effect of injection pressure (IP) which was varied from 300 bar to 500 bar with compression ratio (CR) of 18:1 at 27 bTDC with no load to full load respectively. The engine was operated at a constant speed of 1500 rpm and a common rail direct injection system (CRDI) was adopted to verify the injection pressure effect. The load on the engine was applied with water cooled eddy current dynamometer to 3.5Kw at a maximum speed of 1500 rpm.The engine was connected to a computer capture the data. Pressure of injection was adjusted by using NIRA software to the required value as per the manufactures instruction. Then adjust the water flowing rate and motor water cooling rate were set.Cardanol, HME and diesel blends is filled in fuel tank, engine started with self-inflammation allow warming up the engine in steady condition. It linked the engine to a computer to capture the data. The water flow rate and water cooling rate has been set according to the requirements.

The dynamometer adjusted to required value, once the steady condition reached the fuel rate was noted.Further tests with the same variations of fuel were carried out and to find the emission characteristics an exhaust gas analyzer (Netel exhaust gas analyzer model (NPM-MGA-1) was used to measure the exhaust gas emissions of HC, CO, Nox.Before using the exhaust gas analyzer,it was tested with normal Zero gas. The smoke opacity was measured by using Smoke meter (Netel NPM NGM).Engine specification are given in Table.1.The gas analyzer specification are given in Tables 2 and smoke meter specifications are given in table.3. The percentage uncertainties were calculated for the parameters are shown in table 4

Table1.Specification of CRDI Engine

Product	Product CRDI VCR Engine test (Computerized) Code 244
Engine	Make Kirloskar, Single cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm, 661 cc. Power 3.5 KW, 1500 rpm, CR range 12-18
Dynamometer	Type eddy current, water cooled with loading unit
ECU	Model Nira i7r (with solenoid injector driver) with programmable ECU software and Calibration cable
Common rail	With pressure sensor and pressure regulating valve
Injector	Type Solenoid driven
EGR	SS, Water cooled
EGR	SS, Water cooled

Source: Manufacturer's instructional manual

Table 2. Exhaust gas analyzer accuracy and range (Netelexhaust gas analyzer, Model NPM-MGA 1)

Sl.No	Parameter	Accuracy	Range
1	HC	± 10 ppm	0-20000 ppm
2	CO	± 0.03 ppm	0-9.9 %
3	Nox	± 25 ppm	0-5000 ppm

Source: Manufacturer's instructional manual

Table 3 Smoke meter (Netel make NPM-SM-111B)

Model Name and make	NPM-SM-111B
Display indication	Light absorption coefficient(K)
Display range	0 to 9.9/m
Scale Resolution	0.1/m
Linearity	0.1/m
Response Time	0.3 seconds
Light source details	5mm diameter green LED

Source: Manufacturer's instructional manual

Table 4: Uncertainty of measured values

Sl.No	Parameters	Resolution	Uncertainty (%)
1	HC	1 ppm	± 1.75
2	CO	0.01%	± 1.3
3	Nox	1 ppm	± 0.3
4	Co2	0.01%	± 0.4
5	BTE	--	± 0.5
6	HRR	--	± 1.3

Table 5: Properties of Diesel, Cardanol and HME bio diesel blends

Properties	Higher Calorific value (kJ/kg)	Density (kg/m^3)	Kinematic Viscosity@ 40°C (cSt)	Flash Point (°C)
ASTM Standard	D 240	D 4052	D 445	D 93A
Diesel	46,261	830	2.633	49
Honge biodiesel	39,255	910	11.15	190
Cardanol	41,114	925	26.24	206
C5H10	45011	848	3.279	52
C10H10	44,691	852	3.791	53
C15H10	44,373	858	4.316	53
C20H10	44,243	861	4.822	54

Fig.1 Pictorial view of CRDI VCR C.I.Engine test rig

III. RESULT AND DISCUSSION

III.1 Performance characteristics of blends of Cardanol Honge biodiesel on diesel engine

III.1.1Brake specific fuel consumption (BSFC) ;

During the test of cardanol hybrid biodiesel on CRDI engine ,there is a smooth operation was noted without any noise or uneven speeds in order to obtain better result ,the engine was run for five minutes for stabilization under varied load and for the accurate results. Figure 2(a),(b) and (c) depicts the variation of brake specific consumption of neat diesel and blends of Cardanol, Honge biodiesel with varied load at different injection pressures(IP). It is observed that BSFC decreases as load increased for both diesel and biodiesel blends. BSFC decreases as the injection pressure varied from 300 bars to 500 bars. BSFC increased 9.67 percentas the IP increased from 300 bar to 400 bar and 2 percent increased from 400 to 500 bars injection pressure for C10H10 blend. The temperature in the combustion chamber at higher injection pressure is high So that combustion is complete and BSFC is low. The same trend has been observed by the researcher [17].BSFC depends upon on density, viscosity and calorific values of fuel. At low load rich air fuel mixtures is supplied to the engine resulting in high BSFC and at high load combustion chamber temperature will be high there by reducing ignition delay which helps in complete combustion result in decreasing BSFC.

III.1.2.Brake thermal efficiency (BTE):

The variation of Brake thermal efficiency (BTE) of neat diesel and blends of Cardanol, Honge biodiesel with load at different injection pressure is shown in Figure 3(a),(b) and (c). It is observed that BTE increases as load increases for both neat diesel and biodiesel blends but invariably low for biodiesel blends compared to neat diesel. The BTE of C10H10 Blend at full load at 500 bar injection pressure is close to diesel by 2%. When the injection pressure increased from 300 to 500 bar at full load, BTE increased from 29.12 to 30.28, 30.53 to 31.93, 26.36 to 28.56, 28.61 to 29.65 and 31.2 to 32.54 for C5H10, C10H10, C15H10, C20H10 and diesel respectively. C15H10 and C20H10 gives less BTE from 300 to 500 bar injection pressure The same trends are supported by [17, 18, 20, 21,22]. The reason that as load increases heat loss rate decreases and Brake power increase resulting in an increase in BTE. The Brake thermal efficiency is low for blends because of fact their viscosity and BSFC are high. Also low calorific value and unsaturation condition of biodiesel assists in reducing BTE. As the biodiesel quantity increase in blend, the calorific value decreases there by reducing BTE

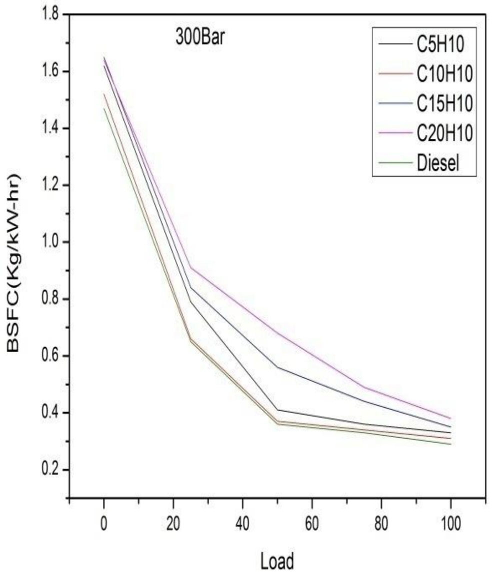
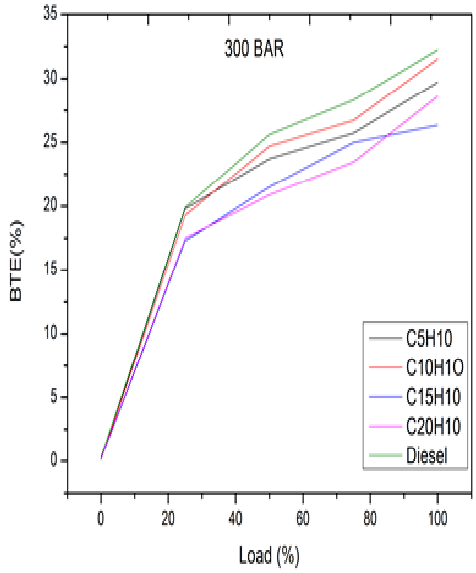


Fig2 (a)



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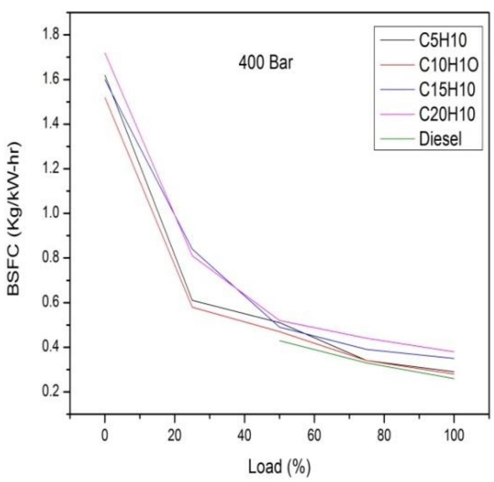

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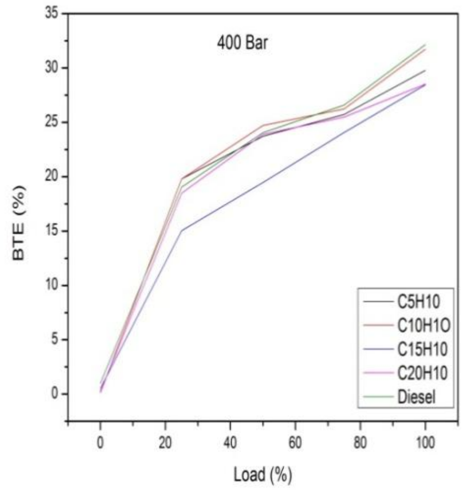


Fig 3(b)

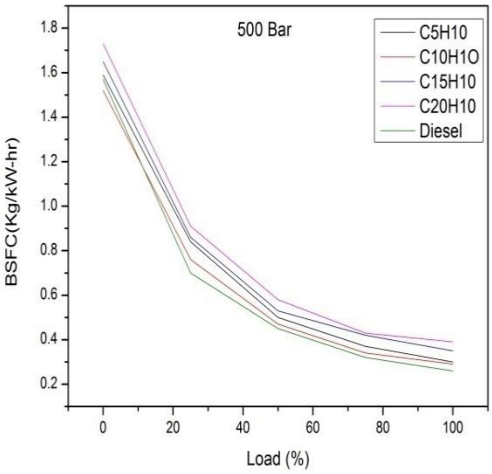


Fig 2(c)

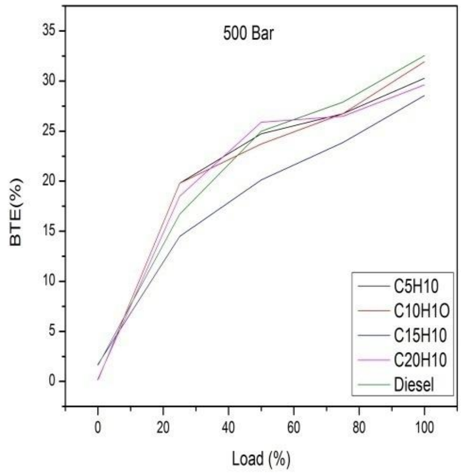


Fig 3(c)

Figure 2.BSFC with load at different Injection pressure (IP) (a)300Bar (b) 400 Bar (c) 500 Bar

Figure.3.BTE with load at different injection (IP) (a)300 Bar (b) 400 Bar (c)500 Bar

III.2.Emission Result:

III.2.1 Unburned hydrocarbon emission (HC)

Figure 4 (a), (b) and (c) shows that HC emission for all fuel measured under different injection pressures at different load. As the load increases the HC emission increased for both bio fuels as well as diesel. It is evident from the figure HC for C10H10 lower than diesel and other blends at 300 to 500 bar injection pressures but C5H10 almost equal to that of diesel fuel. The same trend has been reported similar observation [17,19, 21].The HC emissions for all measured fuels were higher with increase in injection pressure. As the injection pressure increases the delay time is shortened and the combustion is complete, resulting reduced HC emissions. The unburned HC emission present in exhaust charges shows the incomplete combustion of fuelblends in combustionchamber and it depends on parameters like properties of fuel, spray formation and penetration, etc

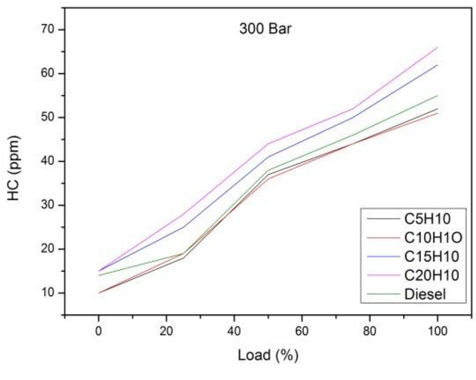


Fig4 (a)

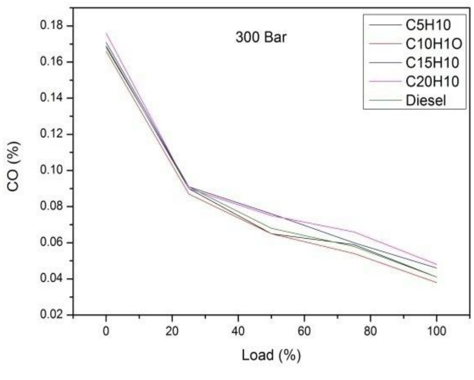


Fig 5(a)

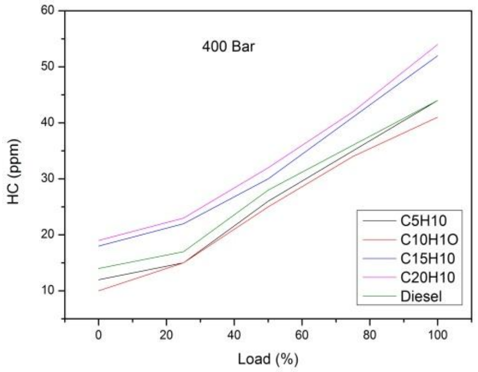
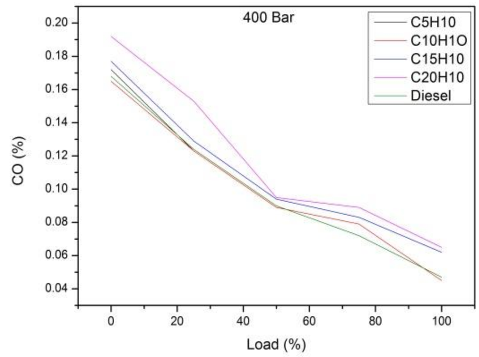


Fig 4(b)



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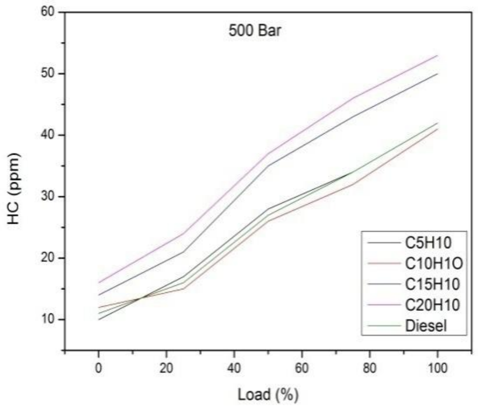

Fig 4(c)

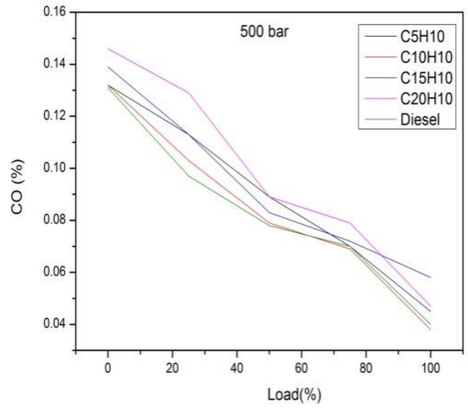

Fig 5(c)

Figure 4.HC with load at different Injection pressure (IP) (a)300Bar (b) 400 Bar (c) 500 Bar

Figure.5.CO with load at different injection (IP) pressure (IP) (a)300 Bar (b) 400 Bar (c)500 Bar

III.2.2 Carbon monoxide (CO)

Figure 5 (a), (b) and (c) shows variations in CO emissions at different injection pressures with load for biofuel blends as well as diesel. The CO emission for the cardanol biofuel blends is decreased with increase in the load.CO emission is low at C10H10 and C5H10 when injection pressure increased from 300 to 500 bar atfull load compared to diesel.CO emissions were higher at C15H10 and C20H10 blend compared to diesel.As quantity of biodiesel increased in the blend CO emission decreased and same trends have been reported similar observation [22].From the figure it is evident that the CO emission was decreased for all biofuel blends and diesel fuel with an increased in injection pressure. This decrease could be attributed to the biodiesels having higher oxygen content than diesel which result in a more complete combustion, leading to less CO in the exhaust stream. It was primarily due to the higher temperature of the air at higher injection pressures, which result in complete combustion. CO emission decreases with increasing amount of biodiesel in the blend.

III.2.3 Nitrogen oxide (NOx) emission

Figure 6(a),(b) and (c) shows the variation of NOx emission with load for different blends at different injection pressures. It is noted from the figure that the NOx emission increases with an increase in the injection pressures. In the combustion chamber oxides of nitrogen were formed due to high temperature and the availability of the excess oxygen inside the combustion chamber This is mainly due to the higher temperature at higher injection pressures and same observation were reported by other researcher [18,19,20].At all the loads, Nox emissions were higher for bio fuel blends than those for diesel fuel. The C10H10 blend released less Nox than the other blends at peak loads. But this emission is slightly larger than diesel fuel emissions were higher for biofuel blends when the injection pressure was increased from 300 bars to 500 bars

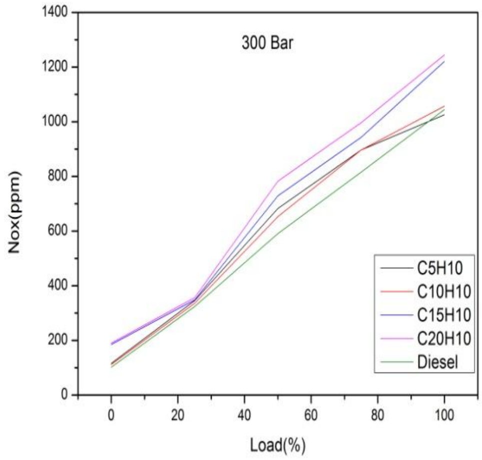

Fig 6(a)

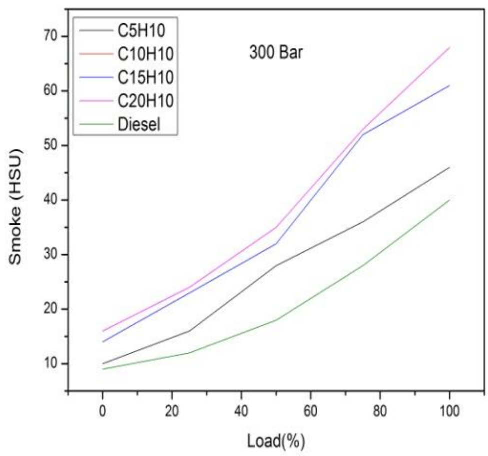

Fig 7(a)

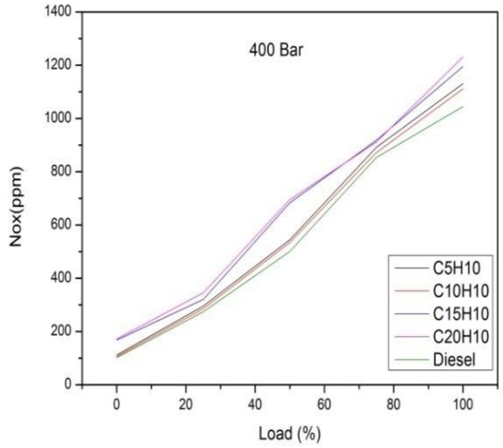

Fig 6(b)

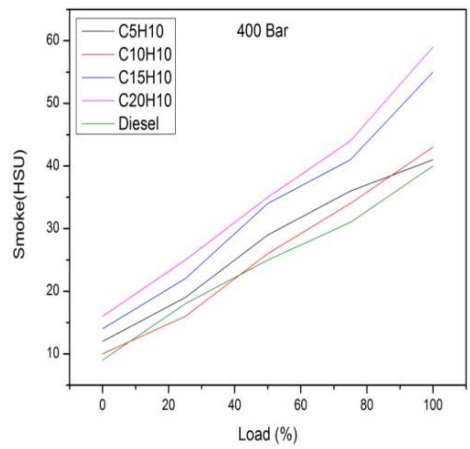

fig 7(b)

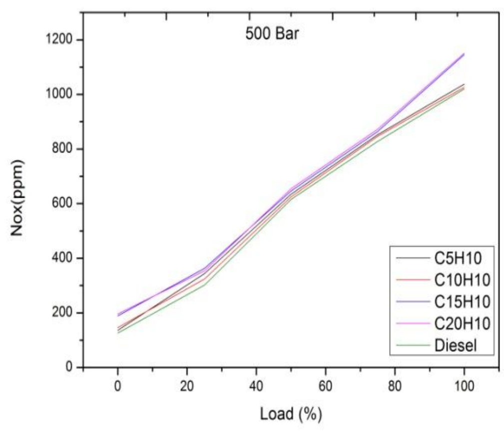

Fig 6(c)

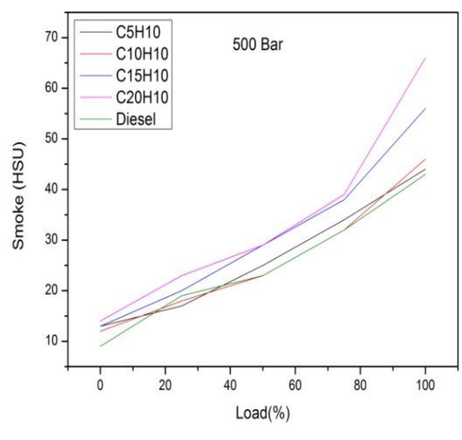

Fig 7(c)

Fig 6 Nox with load at different injection pressure (a)300 bar (b) 400 bar (c) 500 bar

Fig 7Smoke with load at different injection pressure (a)300 bar (b) 400 bar (c) 500 bar

III.2.4 Smoke opacity

Figure 7(a),(b) and (c) shows the variation of smoke emission with load for different blends at different injection pressures. From the figure it can be observed that the smoke increases with an increase in the injection pressures. it is evident that at all the loads smoke is lower for diesel fuel because of the presence of oxygen in the fuel which makes the mixture leaner thereby reducing smoke In the combustion chamber oxides of nitrogen were formed due to high temperature and the availability of the excess oxygen inside the combustion chamber This is mainly due to the higher temperature at higher injection pressures .Same observation were reported by other researcher [20,21,22].At all the loads, Smoke emissions were higher for bio fuel blends than those for diesel fuel. The C10H10 and C5H10 blend released less smoke than the other blends at peak loads. But this emission is slightly larger than diesel fuel emissions were higher for bio fuel blends when the injection pressure was increased from 300 bars to 500 bars

IV. Conclusion

The following conclusion were drawn from the present study

1. Brake Specific Fuel Consumption increased by 6.89% for C10H10 as compared to diesel at 300 bar,7.69% at 400 bar and 11.5% at 500 bar
2. From 300 to 500 bar injection pressure at full load, BTE increased from 29.12 to 30.28 , 30.53 to 31.93 ,26.36 to 28.56, 28.61 to 29.65 and 31.2 to 32.54 for C5H10,C10H10,C15H10,C20H10 and diesel
3. The BTE was 31.93 % for the C10H10 blend at peak load and 28.56 % for the C15H10 blend is less than 3.2% compared to diesel.
4. The CO, HC emissions for the biofuel mixtures were lower than that of diesel from injection pressure increased from 300 to 500 bar.
5. Nox emissions is less for C10H10 at peak load compared to other fuel blends at different injection pressures
6. Smoke emission for C10H10 and C5H10 is less than other blends and higher than that of diesel.

From the aboveinvestigation it can be concluded that 500 bar injection pressure was found optimum with C10H10 blend could improve the performance and emission in diesel engines used as an alternate fuel without any modification of the engine

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