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Experimental Investigation on Performance, Emission and Combustion Characteristics of Single Cylinder Diesel Engine Running on Desert Date (Balanites Aegyptiaca) Biodiesel

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***Abstract*— Continuous rise in the conventional fuel prices and shortage of its supply have increased the interest in the field of the alternative sources for petroleum fuels. In this present work, experimentation was carried out to study the performance, emission and combustion characteristics of desert date biodiesel and its blends. For this experiment a single cylinder, four strokes, naturally aspired, direct injection, water cooled, eddy current dynamometer Kirloskar diesel engine at 1500 rpm for variable loads. Initially, desert date biodiesel and its blends were chosen. The physical and chemical properties of desert date biodiesel were determined. The tests were carried out over entire range of engine operation at varying conditions of load. The engine performance parameters studied were brake horse power, brake specific fuel consumption, brake thermal efficiency, exhaust temperature and mechanical efficiency. The emission characteristics studied are CO, HC, NO_x and smoke opacity. These results are compared to those of pure diesel. These results are again compared to the other results of neat oils available in the literature for validation. By analyzing the graphs, it was observed that performance characteristics are reduced and emission characteristics are lowered compare to the diesel. This is mainly due to lower calorific value, higher viscosity and delayed combustion process. From the analysis of graphs it is observed that B10 and B20 blends are best suited for diesel engine. The present experimental results show that desert date biodiesel and its blends can be used as an alternative fuel in diesel engine.**

Keywords*— Biodiesel; desert date biodiesel; alternative fule; Transesterification; Ethanol; Performance; Emissions; combustion.

I. INTRODUCTION

For more than two centuries, the world's energy supply has relied heavily on nonrenewable crude oil derived liquid fuels. Out of which 90% is estimated as to be consumed for energy generation and transportation. It is also known that emissions from the combustion of these fuels such as CO_2, CO, NOx and sulfur containing residues are the principal causes of global warming. On the other hand, known crude oil reserves could be depleted in less than 50 years at the present rate of consumption. Thus, increased environmental concerns, tougher clean air act standards necessitates the search for a viable alternative fuels, which are environmentally friendly. Oil seed crops such as palm, soyabean, sunflower, peanut, olive etc are by far the largest group of exploitable renewable biomass resource for liquid fuel and energy generation.[1]

The attractive features of bio-diesel fuel are:

- It is a plant derived, not petroleum derived, and such its combustion does not increase current net atmospheric levels of CO2, a 'greenhouse' gas.
- It can be domestically produced, offering the possibility of reducing petroleum imports.
- It is biodegradable.
- Relative to conventional diesel fuel, its combustion products have reduced level of particulates, carbon monoxide, sulfur oxides, hydrocarbons etc.
- Vegetable oils can be used in diesel engines as they have high octane number and calorific value very close to diesel.

The present work aims to investigate the possibilities of the application of mixtures of biodiesel with diesel as a fuel for diesel engines. The present investigations are planned after a thorough review of literature in this field. The combinations of desert date biodiesel, along with diesel are taken for the experimental analysis.

II. EXPERIMENTAION

A. *Transesterification*

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification. This esterifies vegetable oil is called bio-diesel. Biodiesel properties are similar to diesel fuel. It is renewable, non-toxic, bio-degradable and environment friendly transportation fuel. After esterification of the vegetable oil its density, viscosity, cetane number, calorific value, atomization and vaporization rate, molecular weight, and fuel spray penetration distance are improved more. So these improved properties give good performance in CI engine.

B. Separation of glycerol from bio- diesel

Fig-1 Seperation of glycerin

The Fig -1 shows the separation of glycerin from the bio- diesel. After reaction the oil is kept in a settling funnel for the process of separation. In which biodiesel, glycerin and catalyst are separated

III. EXPERIMENTAL SET-UP

Experiments were performed in the internal combustion engine laboratory, Department of mechanical engineering, PDA College of engineering, Gulbarga. The experimental setup consists of single cylinder, four strokes, diesel engine connected to eddy current dynamometer for variable loading. The set as stand- alone type independent panel box consisting of air box, fuel tank, manometer etc. The set up enables study of engine for brake power, BMEP, brake thermal efficiency, mechanical efficiency, specific fuel consumption, volumetric efficiency, A/F ratio, and emission characteristics like CO, CO2, HC and NO_X.

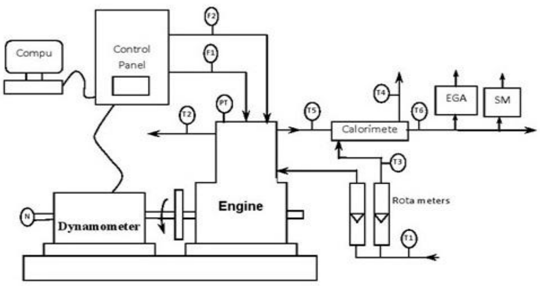

Fig. 2 Experimental Setup

PT	Pressure transducer	T1	Jacket water inlet temperature
N	Rotary encoder	T2	Jacket water outlet temperature
F1	Fuel flow	T3	Calorimeter water inlet temperature = T1
F2	Air flow	T4	Calorimeter water outlet temperature
F3	Jacket water flow	T5	Exhaust gas to calorimeter temperature
F4	Calorimeter water flow	T6	Exhaust gas from calorimeter temperature

The various components of experimental set up are described. Fig.2 shows line diagram and fig.3.shows the photograph of the experimental set up. The important components of the system are,

- The engine
- Dynamometer
- Exhaust emission testing machine
- Calorimeter
- Fuel measuring unit
- Pressure sensor
- Temperature sensor
- Rotameter
- Software

Fig 3 Photograph of experimental setup

Table 1 Technical specifications of the engine.

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV–SR II, naturally Aspirated
Engine	Single cylinder, DI, 4 strokes
Bore/stroke	87.5mm/110mm
Compression ratio	17.5:1
Speed	1500 r/min, constant
Rated power	5.2 kW
Injection pressure	240 bar/23° BTDC
Type of sensor	Piezo electric
Crank angle sensor	1-degree crank angle

A. *Exhaust emissions testing machine*

Fig. 4. Emission testing machine

The emissions test is are done with AVL DITEST MDS 350 Exhaust Gas Analyzer. It is designed with sophisticated measurement modules. The product has additional features to save a vehicle and customer database, radio-connected diesel measuring chamber up to the option of designing the protocols individually. Due to the robustness and intuitive application of the device, the tester can be used to get sophisticated and accurate emission measurements. This provides for motivation and satisfaction. Fig.4 shows the emission testing machine.

IV. RESULTS AND DISCUSSION

A. *Fuel properties and characteristics*

The proprieties of the desert date biodiesel, diesel fuel and blends were determined and the results are shown in Table: 2

Table 2 Properties of diesel and desert date biodiesel blends

Properties	Diesel	BD 10	BD 20	BD 100	Equipment	BIS Specification
Calorific value (KJ/Kg)	42000	41953	41906	41532	Bomb calorimeter	-
Kinematics viscosity at 40^{0}C (Cst)	2.54	2.79	3.05	5.1	Red wood viscometer	2.5 – 6.0
Density (kg/m^3)	830	835	839	875	Hydrometer	860-900
Flash Point (^{o}C)	54	65	76	165	Pensky marten’s	≤ 120
Fire Point (^{o}C)	64	75	88	175	Pensky marten’s	-

B. *Performance characteristics*

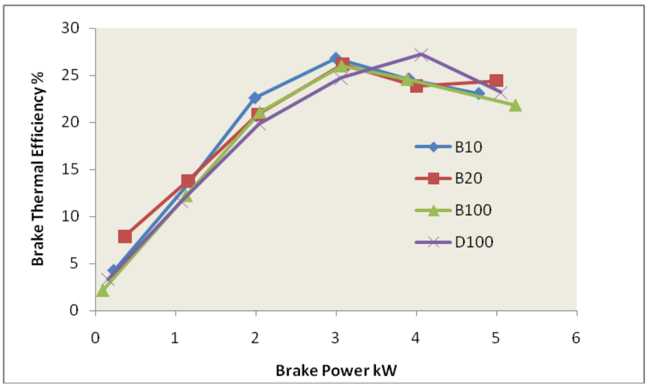

Fig -5: Variation of brake thermal efficiency with brake power

The variation of brake thermal efficiency with brake power for diesel, desert date biodiesel and their blends are shown in Fig 5. Brake thermal efficiency is increasing with increasing brake power for all multi-blends of biodiesel and diesel. It may be due to reduction in heat loss and increase in power with increase in load. Brake thermal efficiency of 10% blend is very close to diesel for entire range of operation. Maximum brake thermal efficiency of 10% blend is 26.82% against, 27.22% of diesel oil, which is lower by 0.4%. We can say that brake thermal efficiency of 10% blend is very well comparable with diesel. The maximum brake thermal efficiency of 20% and neat desert date oil are 26.18% and 26.037% against 27.22% of diesel.

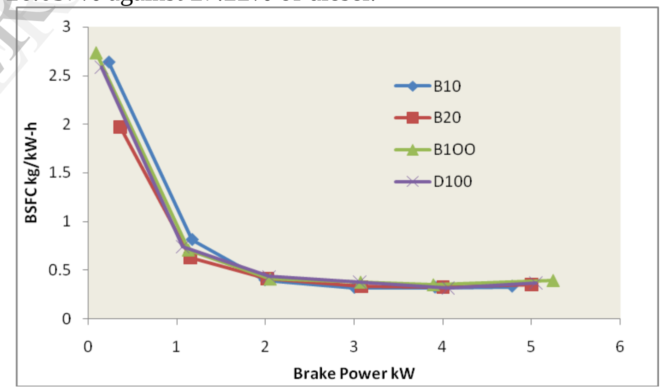

Fig -6: Variation of specific fuel consumption with brake power

The variation of brake specific fuel consumption (BSFC) with brake power for diesel, desert date oil and its blends shown in Fig 6.BSFC of 10% blend closely matches with diesel, followed by 20% blend. Minimum BSFC of 10% blend and 20% blend are 0.318 kg/kW-h and 0.322 kg/kW-h against 0.315 kg/kW-h of diesel oil. BSFC of neat desert date biodiesel oil is 0.037 kg/kW-h higher than of diesel oil.

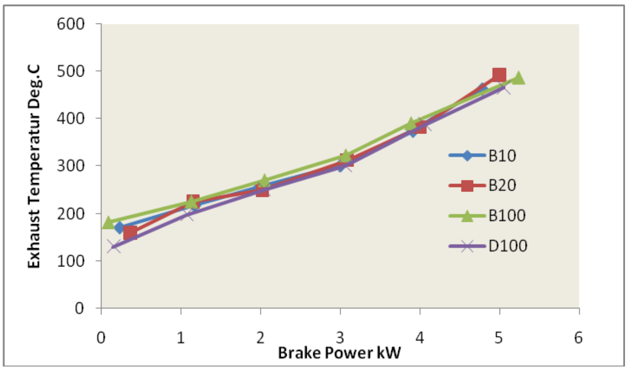

Fig -7: Variation of exhaust gas temperature with brake power

Fig 7 shows the variation of Exhaust Temperature (ET) with brake power output for desert date biodiesel and its blends with diesel in the test engine. The exhaust temperature of 10% blend of desert date biodiesel has lower values compared with all other blends and is well comparable with diesel, the exhaust temperature of all blends and diesel increases with increase of operating load. The 10% blend of desert date biodiesel has higher performance than other blends due to reduction in exhaust loss.

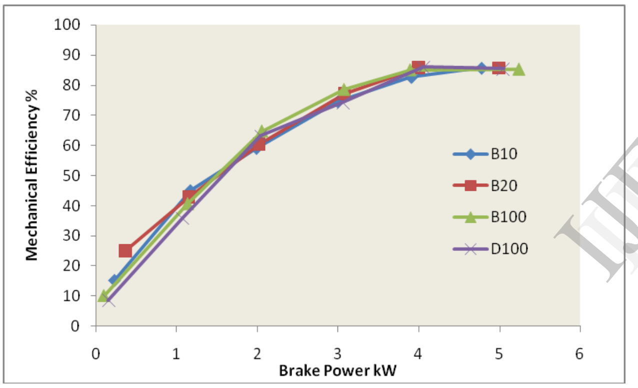

Fig -8: Variation of mechanical efficiency with brake power

The variation of mechanical efficiency with brake power, for diesel and desert date biodiesel blends is shown in figure 8. The mechanical efficiency of diesel is slightly higher than the desert date biodiesel. Mechanical efficiency of 20% blend is very close to diesel, followed by 10% blend for entire range of operation. Maximum mechanical efficiency of 20% and 10% blend is 85.8% and 85.71% against, 86.01% of diesel oil. The maximum mechanical efficiency of neat desert date biodiesel is 85.2%. From the graph it is evident that with increase in concentration of desert date biodiesel in neat diesel oil decreases the mechanical efficiency. This may be due to better lubricating property of the diesel which reduces frictional losses.

C. *Emission Characteristics*

Fig.9 shows the variation of carbon monoxide emission with brake power for desert date biodiesel oil and its blends in the test engine. The CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. CO emission of all blends is higher than that of diesel. Among the blends 10% blend has a lower CO emission followed by 20% blend. CO emission of 10% and 20% blends at maximum load is 0.03% and 0.042% volume against 0.028% volume of diesel. CO emission of neat desert date biodiesel is higher than all other blends for entire operating range and maximum of 0.05% occurs at the rated load. This due to incomplete combustion at higher loads which results in higher CO emissions.

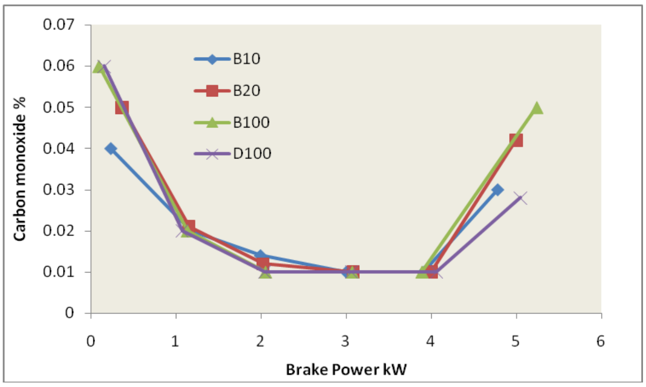

Fig -9: Variation of carbon monoxide with brake power

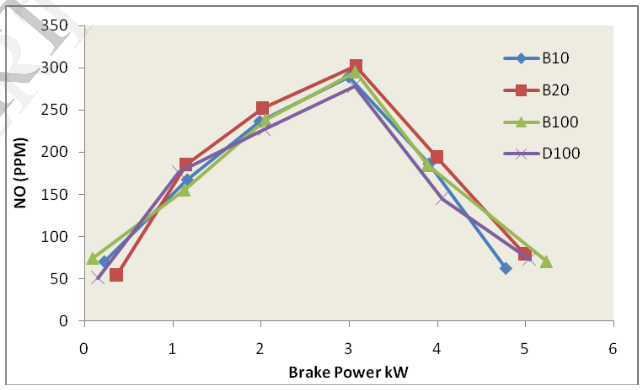

Fig -10: Variation of NOx with brake power

Fig. 10 shows the variation of nitrogen oxides emission with brake power output for desert date biodiesel oil and its blends with diesel in the test ring. The NO_x emission for biodiesel and its blends is higher than that of diesel. The NO_x of 10% blend is very close to diesel for entire range of operation followed by the neat biodiesel. The maximum NO_x emission of 10% and neat biodiesel is 289ppm and 295ppm against 278ppm of diesel. The maximum NO_x emission for the 20% blend is 295ppm.

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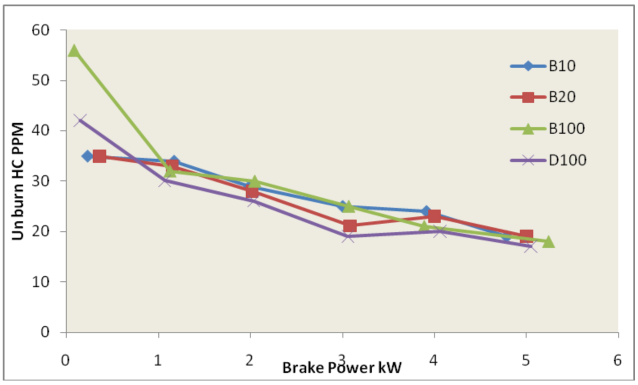

Fig -11: Variation of hydrocarbon with brake power

Fig 11 shows the variation of emission of hydrocarbon with brake power for different blends of desert date biodiesel and pure diesel. The emission of HC is decreasing with increase of loads. UHC of neat biodiesel has lower emission compared with all other blends followed by 20% blend. The minimum value of UHC at neat biodiesel is 18 ppm against 17 ppm of diesel. The minimum value of UHC for both 10% and 20% is 19 ppm.

D. Combustion Characteristics

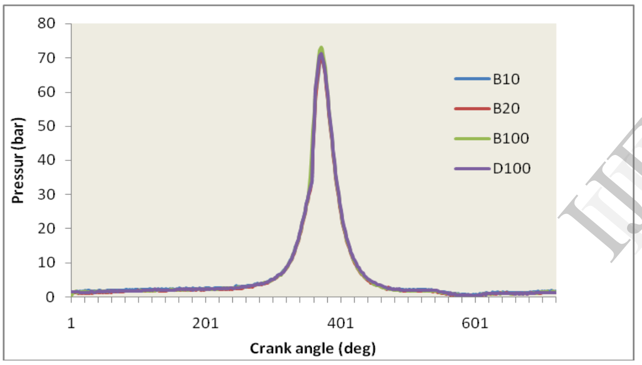

Fig -12: Variation of pressure with crank angle

The variation of pressure with crank angle for diesel, desert date biodiesel and their blends are shown in Fig 12. In a CI engine the cylinder pressure is depends on fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. It can be seen from Figure (4.5) that neat desert date biodiesel had a higher peak pressure than that of neat diesel.

The variation of Net heat release rate with crank angle for diesel, desert date biodiesel and their blends are shown in Fig13. The heat release rate for all other tested fuel was slightly less than that of diesel this may be attributed to low vaporization, high viscosity and low peak pressure of blends as compared to that of diesel. Heat release rate of neat biodiesel is very close to diesel for entire range of operation, followed by 10% blend. The maximum heat release rate for neat biodiesel and 10% blend is 41.05 J/deg and 39.85 J/deg against 44.05 J/deg of diesel oil.

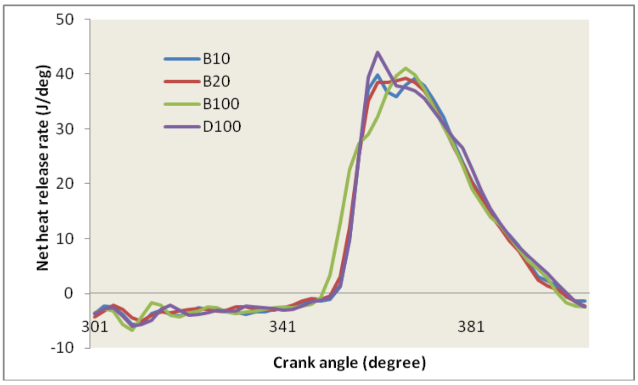

Fig -13: Variation of Net HRR with crank angle

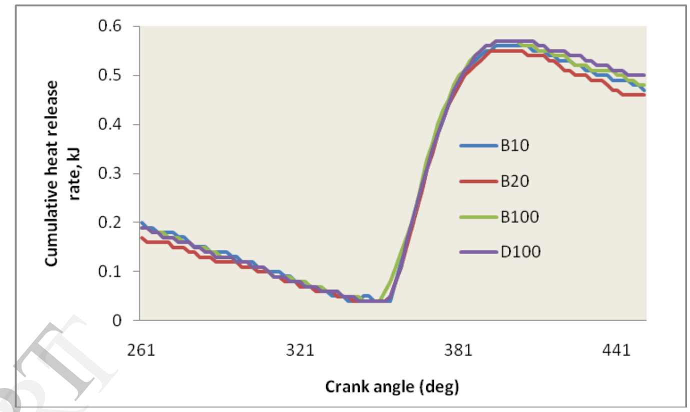

Fig -14: Variation of cumulative heat release rate with

The variation of cumulative release rate with crank angle for diesel, desert date biodiesel and their blends are shown in Fig14. The maximum cumulative heat release for neat biodiesel has same value of diesel oil i.e. 0.57 kJ. Maximum cumulative heat release rate for 10% and 20% blends are 0.56 kJ and 0.55 kJ, against the diesel of 0.57 kJ. This may be due to Once the ignition delay period is passed, the premixed fuel air mixture burns very fast, releasing the heat very rapidly and then diffusion combustion takes place. During the latter it is possible to control the burning rate by regulating the quantity of available air-fuel mixture

E. Comparison of desert date biodiesel performance and emission characteristics with deccan hemp and honne oil

To ascertain the validity of result obtained, desert date biodiesel performance and emission characteristics is compared with the similar experimental work of O.D. Hebbal [3] and B.K.Venkanna [13]

O.D. Hebbal conducted the variable load performance test with deccan hemp. Then the performance of engine is evaluated in terms of brake thermal efficiency, BSFC, unburnt HC, CO emission and exhaust temperature. B.K.Venkanna also conducted the variable load test with honne oil. Then the performance of engine is evaluated in terms of brake thermal efficiency, unburnt HC, CO emission and exhaust temperature. Though the performance result are available for blends, for convenience only the result of neat vegetable oils are used for comparison. The results are plotted with trend lines for easy understanding. For the purpose of comparison deccan hemp oil used by O.D.Hebbal is labeled as DH100 and honne oil used by B.K.Venkanna is labeled as H100.

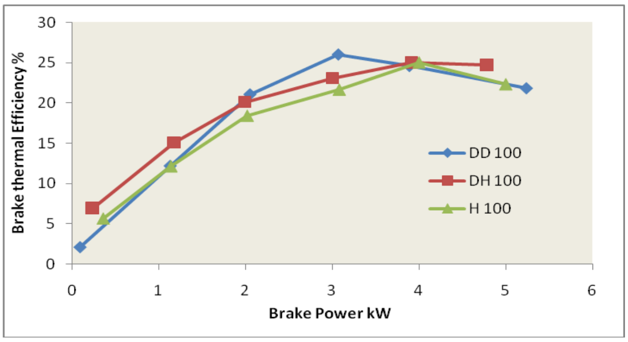

Fig -15: Variation of brake thermal efficiency with brake power

Fig-15 shows the variation of brake thermal efficiency with brake power. The brake thermal efficiency of desert date biodiesel is higher than that of other oils. The maximum thermal efficiency desert date is 26.0375% and DH100 and H100 is 25.063% and 25.01% respectively.

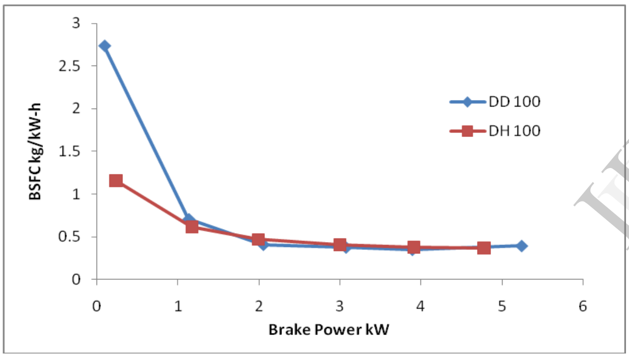

Fig -16: Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power shows in fig-16. The BSFC of an deccan hemp is higher than that of desert date biodiesel, the minimum BSFC of desert date biodiesel and deccan hemp oil is 0.352 kg/kW-h and 0.371 kg/kW-h respectively.

Fig-17 shows the variation of exhaust temperature with brake power. Exhaust temperature of the desert date biodiesel is lower than the other oil. The maximum temperature of desert date biodiesel, DH 100 and H100 is 486.94°C, 524°C and 556°C respectively.

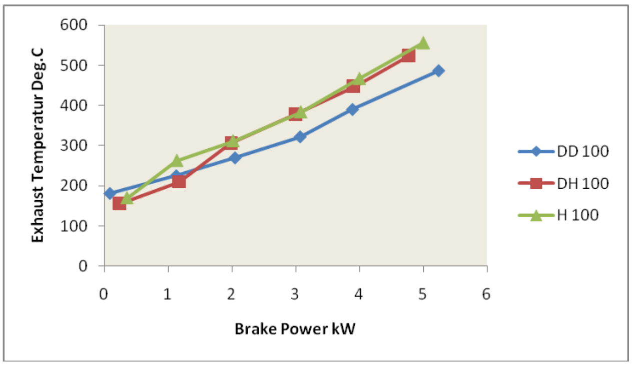

Fig -17: Variation of exhaust gas temperature with brake power

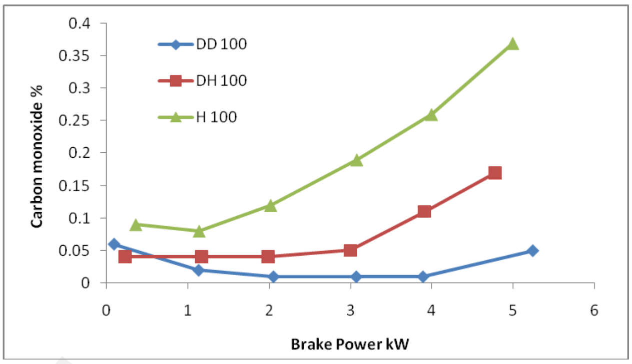

Fig -18: Variation of carbon monoxide with brake power

The variation of carbon monoxide with brake power is shown in fig-18. The CO value for value for desert date biodiesel is lower than the other biodiesel. The maximum CO value for desert date biodiesel, DH100 and H100 is 0.05%, 0.17% and 0.37% respectively.

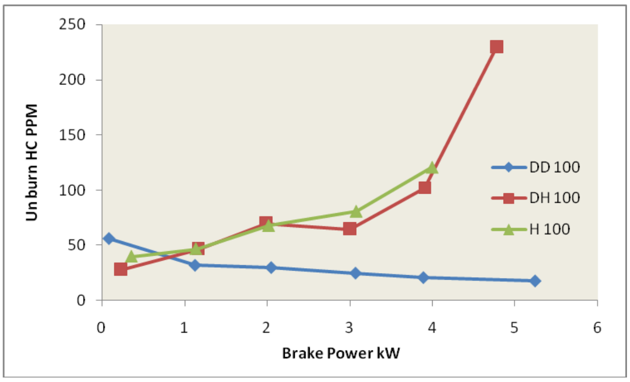

Fig -19: Variation of hydrocarbon with brake power

The variation of unburnt HC with brake power is shown in fig-19. The values of HC for DH100 and H100 are increases with the increases of load, but in case of desert date biodiesel is decreases with the increases of load.

V. CONCLUSIONS

Experimental investigations are carried out on a single cylinder diesel engine to examine the suitability of desert date biodiesel as an alternate fuel. The performance, combustion and emission characteristics of blends are evaluated and compared with diesel. No difficulty was faced at the time of starting the engine and the engine ran smoothly over the range of engine speed. From the above investigation, the following conclusions are drawn.

- The properties viz; density, viscosity, flash point and fire point of desert date biodiesel is higher and calorific value is 0.98 times that of diesel.
- Performance, combustion and emission characteristics of 10% blend is better than other blends, followed by 20% blend. And efficiency of 10% blend is well compare with the diesel. The maximum brake thermal efficiency of 10% and 20% are respectively 26.82% and 26.18% against, 27.22% of diesel.
- The maximum brake thermal efficiency of neat desert date biodiesel is 26.037% against 27.22% of diesel.
- The minimum BSFC of neat biodiesel is 0.037 kg/kW-h higher compared with diesel.
- Unburnt HC, CO and NO_x emissions at maximum load for neat desert date biodiesel compared with diesel are higher by 1ppm, 0.022 vol%, and 17ppm, respectively.
- After comparison of desert date biodiesel with deccan hemp and honne oil it is concluded that, the brake thermal efficiency of desert date biodiesel is higher than that of other oils for entire range of operation.
- The maximum brake thermal efficiency of desert date biodiesel, DH100 and H100 are 26.0375%, 25.063% and 25.01% respectively.
- The CO emission and unburnt HC of desert date biodiesel is lower than D100 and H100.this could be the reason for higher efficiency of desert date biodiesel. The maximum value of CO for desert date biodiesel, DH100 and H100 are 0.05%, 0.17% and 0.37% respectively.

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