# PERFORMANCE AND EMISSION ANALYSIS OF A DIESEL ENGINE BY ADDING ALUMINA NANOPARTICLES AND SURFACTANT TO DUALBIODIESEL AND DIESEL BLENDED FUEL

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***Abstract :*** ***An experiment is carried out to evaluate the performance and emission characteristics using dualbiodiesel and diesel blended fuel prepared by adding Aluminum oxide ($Al_2O_3$) nanoparticles and Surfactant in the fuel. These nanoparticles are added to the fuel along with a Surfactant by sonication method and used as a fuel in a diesel engine and results are compared with pure diesel . Results shows that the addition of the nanoparticles and Surfactant increase thermal efficiency by 3% with a slight decrease in fuel consumption and reducing emissions appreciably.The performance and emission characteristics of a diesel engine can be improved and dualdiesel diesel blended fuel can be claimed to be a potential alternative to diesel in diesel engines.***

***IndexTerms - Dualbiodiesel, Uitrasonication, Nanoparticles , Surfactant, Ignition delay, Ignition duration***

## I. INTRODUCTION

Nano technology has been claimed to be an attraction in the world that can be attributed to major breakthrough in the fields of energy and environment. The nanoparticles or nanopowders can bring numerous changes in physical properties. Parameters such as the ratio of surface area to volume, and size of the particle can be considered as important factors in the development of nanofluids in the near future.

In recent years, several experimental studies have focused on dual fuel blends containing one or more bio-fuels forming a combination of bio-fuels with high and low viscosities so that the combined viscosity remains comparable with that of diesel. Experiments with various combinations of biodiesel-methanol, biodiesel-ethanol, cashew nut shell oil-camphor oil, biodiesel-eucalyptus oil etc. are in progress. In this context, Mohsin et al. [8] studied the effects of the biodiesel-CNG blend on engine performance and exhaust emission of diesel engine, dual fuel, results indicated better exhaust emission as well as improvement in fuel economy as compared to the base fuel. Devan and Mahalaxmi [10] used the combination of eucalyptus oil and methyl ester derived from paradise oil replacing conventional diesel completely; they reported improvements in emission levels and performance was found compared with pure diesel. Anand et al. [12] experimented with 10% methanol and 90% Karanj methyl ester in place of diesel and observed improvement in emission characteristics, especially **$NO_X$** and smoke, combustion, and performance of diesel engines. Vallinayagam et al. [9] investigated a dual bio-fuel (pine oil and kapok methyl-ester) strategy to eliminate diesel completely and reported that these fuels could be used directly in diesel engines without any modifications and their emissions HC, CO and smoke reduced by 8.1%, 18.9% and 12.5% respectively at full load and **$NO_X$** emission remained similar to the standard diesel.

One of the major conclusions of the numerous investigations concentrating on the strategy of using bio-fuel having a lower viscosity with either diesel or biodiesel in larger proportions essentially depends on the calorific value of the less viscous fuel component [9, 32]. Thus, the alcoholic bio-fuels such as methanol and ethanol can only be used in smaller proportion because of their lower heating values and high latent heat of vaporization [25, 26]. Further, eucalyptus oil and pine oil also has lower viscosity but simultaneously their heating values are comparable to that of diesel; therefore, they can be used in higher proportions as compared to the alcohols [9, 11]. Table III shows the viscosity and heating values of some of the potential bio-fuels having the low viscosity which can be used with diesel or biodiesel. It is clear from the data enlisted in Table III that properties of Jatropha biodiesel such as the heating value being almost comparable with that of diesel and low cost makes it a better candidate to be used with biodiesel. Although there has already been the some work has been done on Rubber seed biodiesel [1], blending of Jatropha biodiesel with Rubber seed biodiesel has not been studied till now. In the present work, experiments on the blend of Jatropha biodiesel and Rubber seed biodiesel having in 50:50 by volume proportions will be designed with a view to eliminate diesel completely yet the improvements in engine performance and emission characteristics can be contemplated. In this study, the combustion, performance and emission characteristics will be comprehensively analyzed and compared for a single cylinder four stroke diesel engine without any modification.

## II. EXPERIMENTAL STUDY

### 2.1 Fuel formulation

Stable and homogeneous mixture of dualBiodiesel in base diesel with alumina nanoparticle and surfactant blended fuel containing two bio-fuels forming a combination of both bio-fuels with less cost is formulated so that the combined cost remains smaller compared to that of diesel. Surfactant Triton X100 is used for studying its effect on the performance and emissions of a Diesel engine. Experiments with various combinations of biodiesel-methanol, biodiesel-ethanol, cashew nut shell oil-camphor oil, biodiesel-eucalyptus oil etc. are in progress.

Table 1 Properties Of Less Cost Fuel & Bio-Fuels

| | Bio-fuel | Cost(Rs.) | Energy cost(Rs./MJ) | Calorific Value ((KJ/Kg) | Reference |
|---|---|---|---|---|---|
| 1 | Diesel | 60 | 1.12 | 42500 | [10] |
| 2 | Jatropha | 35 | 1.15 | 39500 | [3] |
| 3 | Rubberseed biodiesel | 38 | 1.17 | 36500 | [1] |
| 4 | Coconutoil biodiesel | 65 | 1.73 | 36770 | [26] |
| 5 | Palm oil biodiesel | 64 | 1.81 | 34750 | [27] |

### 2.1.1 Nomenclature of fuel composition

Specification of fuels and their composition used for the experimental study are shown in Table 2.

Table 2 Specification Of Fuel Composition

| S.No. | Fuel | Blend |
|---|---|---|
| 1 | Pure Diesel | D100 |
| 1 | 100%Diesel+40 PPM $Al_2O_3$ | D100Al40 |
| 2 | 80% Diesel + 10%JBD+10%RSBD | B20 |
| 3 | 80%Diesel+10%JBD+10%RSBD+40 PPM $Al_2O_3$ + 1% Triton X100 | B20Al40S1 |
| 4 | 80%Diesel+10%JBD+10%RSBD+40 PPM $Al_2O_3$+ 2% Triton X100 | B20Al40S2 |
| 5 | 80%Diesel+10%JBD+10%RSBD+40 PPM $Al_2O_3$+3% Triton X100 | B20Al40S3 |
| 6 | 80%Diesel+10%JBD+10%RSBD+40 PPM $Al_2O_3$+4% Triton X100 | B20Al40S4 |
| 7 | 80%Diesel+10%JBD+10%RSBD+40 PPM $Al_2O_3$+5% Triton X100 | B20Al40S5 |

### 2.2 Evaluation of Properties of fuel

The biodiesel fuels, methyl ester composition estimated their thermophysical properties. The properties of biodiesel fuels are evaluated based on the assumption that biodiesel is pseudo-components of Kay's rule [34].

Where Xi = methyl ester component molar fraction, Mi = property of methyl ester and M= the property of biodiesel

Properties of turpentine oil and Jatropha methyl ester and dual fuel blends (Jatropha biodiesel and Turpentine oil) are given in Table 3.

Table 3 Properties Of Fuels Used

| S. No. | Items | Pure Diesel | Rubberseed BD | Jatropha BD | D100Al40 | B20 | B20Al40 S1 | B20Al40 S2 | B20Al40 S3 | B20Al40 S4 | B20Al40S 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Calorific Value (kJ/Kg) | 42500 | 36500 | 39500 | 42550 | 40236 | 40436 | 40636 | 40840 | 41240 | 41440 |
| 2. | Viscosity@ 40 $^0$ C($mm^2/s$) | 3.21 | 5.81 | 4.12 | 4.00 | 4.01 | 4.08 | 4.12 | 4.17 | 4.23 | 4.28 |
| 3. | Cetane index | 47.14 | 43 | 48.13 | 47.54 | 45.63 | 45.84 | 46.24 | 45.63 | 45.45 | 45.23 |
| 4. | Density ($Kg/m^3$) | 0.831 | 0.874 | 0.881 | 0.892 | 0.900 | 0.892 | 0.885 | 0.865 | 0.845 | 0.815 |
| 5. | Flash point, $^0$C | 76 | 130 | 165 | 72 | 148 | 135 | 130 | 143 | 148 | 152 |

### 2.4 Specification of Engine

The experiments are carried out on a single cylinder, direct injection, Kirloskar TV1, water cooled, naturally aspirated engine . AVL 437C exhaust gas analyzer attached to the computer was used for the measurements of various exhaust gas parameters like CO, HC,Opacity and $NO_X$ .Technical specifications of the engine are given in Table 4.

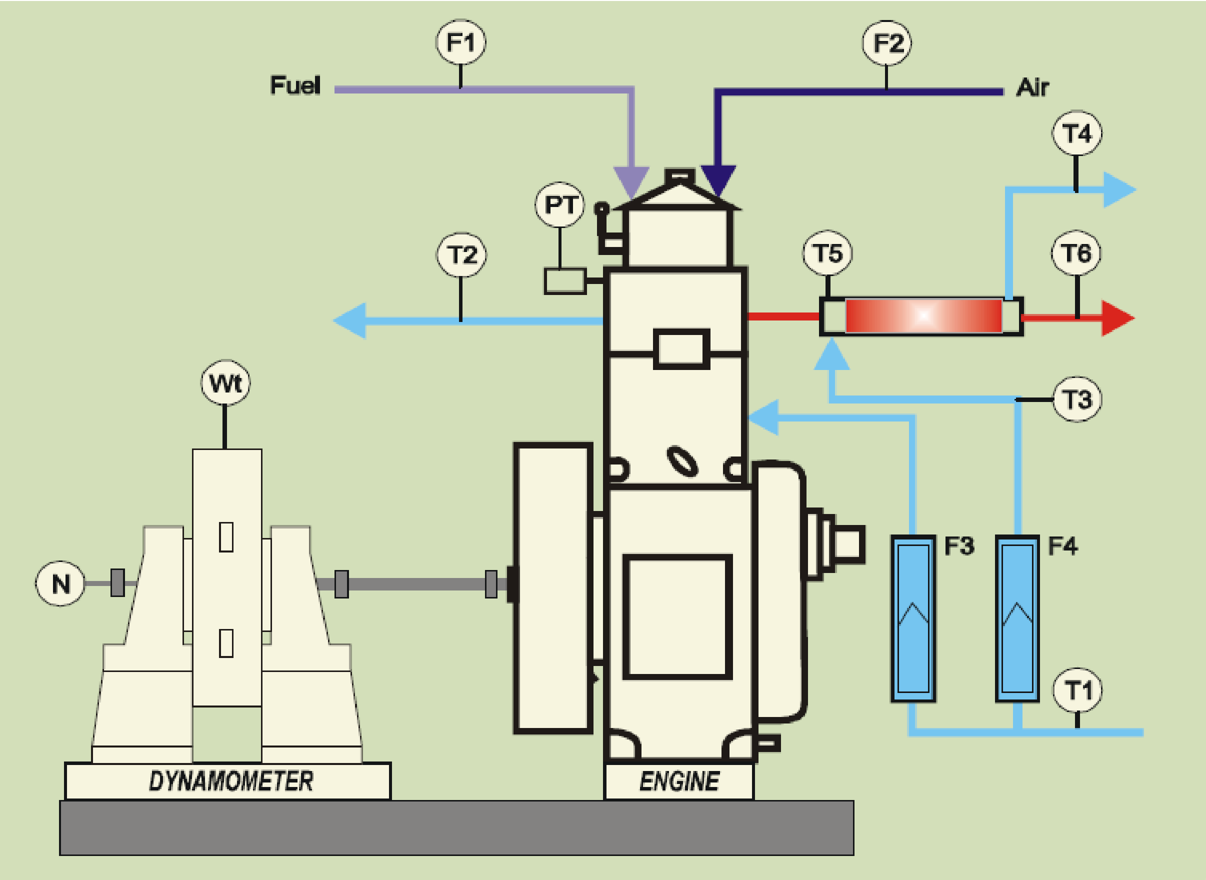


Fig. 1.Engine Test setup

Table 4 Specification Of Engine Setup

| | |
|---|---|
| Model | TV1, Kirloskar oil Engine Ltd. India |
| Type | Single Cylinder, Four stroke, water cooled, constant speed, direct injection, compression |
| Bore | 87.5 mm |
| Stroke | 110 mm |
| Max power | 5.2 kW |
| Speed | 1500 rpm |
| Compression ratio | 17.5:1 |
| Injection pressure | 210-220 bar |
| Governor | Mechanical (centrifugal) type |
| Dynamometer | Eddy current |
| Pressure Sensor | Kistler |
| Crank angle | magnetic TDC pick up sensor |
| TDC at | 360 crank Angle |
| Start of Injection at | 23 deg before TDC |
| Sensor response | Piezo electric |
| Time sampling | 4 µsecond |
| Resolution crank | 1deg crank angle |
| Fuel flow measurement | Burette with digital stopwatch |

## III. Results & Discussion

The combustion phenomenon of the internal compression engine depends on various parameters such as fuel injection pressure, heat release rate, combustion duration, mixing of fuel with air, the inlet temperature of the air, ignition delay and fuel properties like viscosity, calorific value, flash point, density, volatility etc.

In the present investigation, experiments are carried out to estimate combustion, performance and emission parameters of a diesel engine by using dualBiodiesel (Jatropha biodiesel & Rubberseed biodiesel ) and mineral diesel blends with $Al_2O_3$ laden fuel. Blends of Jatropha methyl ester and Rubberseed biodiesel known as dualBiodiesel and diesel laden with $Al_2O_3$ nanoparticle fuel blends were used and experimental observations were collected to compare the performance and emission properties of blended fuel . The engine was loaded in the range of 25%, 50%, 75%, and full load for the constant speed of 1500 rpm.

### 3.1. Brake Thermal Efficiency

Brake thermal efficiency (BTE) of the engine is the fraction of fuel energy converted to useful power output. I t is used for evaluating the performance of an engine. Fig. 2 illustrates the variation of brake thermal efficiency with load. The dualBiodiesel fuel blends have higher BTE at no load to full load conditions than standard diesel fuel. It is also observed that BTE improved is due to the reduction in friction losses and increases in brake power with the increase in load. The lower volatility and higher viscosity of Jatropha biodiesel resulted in the poor fragmentation and combustion characteristics, but oxygen molecules present in the dualBiodiesel fuel blends slightly improves the combustion characteristics. Therefore, BTE was found to be higher for all dualBiodiesel fuel blend compared to conventional diesel fuel. Chauhan et al. [2] reported low BTE, when tested with the blend of diesel and Jatropha methyl ester. Kumar et al. [17] investigated the Jatropha methyl ester and methanol blends on the diesel engine and reported low BTE. Paula et al. [3] investigated the diesel and Jatropha methyl ester oil on a diesel engine and reported the lower BTE than diesel fuel. Anand et al. [12] examined the conventional diesel and turpentine fuel on the diesel engine and reported low BTE than the conventional diesel fuel. It was observed that the magnitude of BTE for pure diesel, B20 , B20Al40S1, B20Al40S2, B20Al40S3, B20Al40S4 , B20Al40S5 and D100Al40 was found to be 29.44, 34.29, 35.18, 35.48,34.85,34.34 ,33.94 and 33.14 for full load condition respectively. It can be shown from the figure that the thermal efficiency (BTE) for dualBiodiesel and all its diesel blends laden with nano particles is higher compared to the pure diesel.

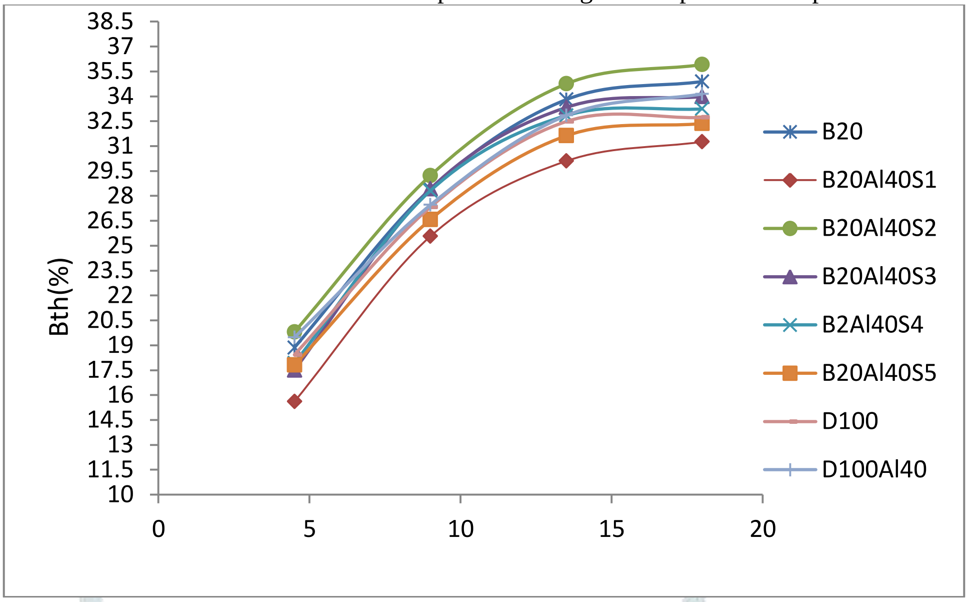


Fig. 2. Variation of $B_{th}$ at different engine loads

### 3.2. Specific Fuel Consumption

Fig.3 shows the Variation of BSFC at different engine loads for dualBiodiesel and its diesel blends laden with nano particles.The Specific Fuel Consumption for standard diesel, B20, B20Al40S1, B20Al40S2, B20Al40S3, B20Al40S4 , B20Al40S5 and D100Al40 fuel blends were measured to be 0.26, 0.26, 0.25,0.25, 0.25, 0.25, 0.25, and 0.26 respectively at full load. It may be due to the cetane rating of the fuel; standard diesel fuel has a higher cetane rating than dualBiodiesel and dualBiodiesel and diesel blends laden with nano particles. In addition to this, the temperature of combustion chamber also plays an important role in fuel ignition.However it can be shown from the figure that fuel consumption for dualBiodiesel and its diesel blends laden with nano particles is comparable to the pure diesel.

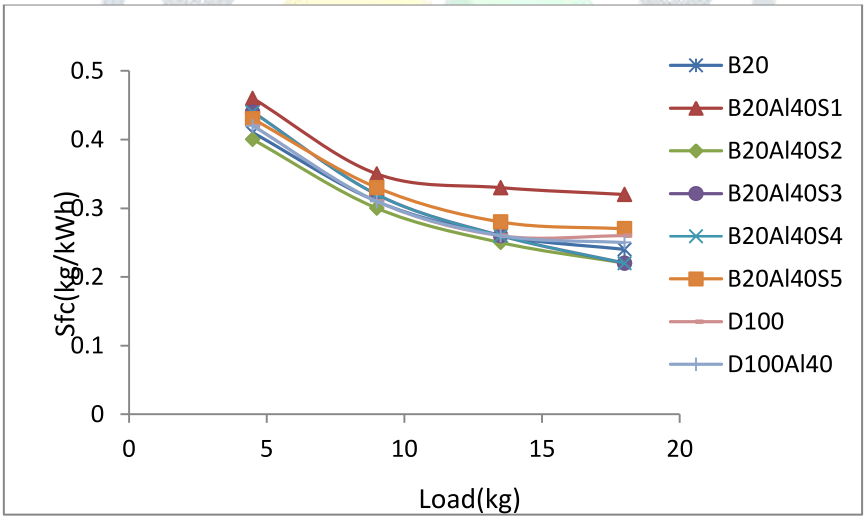


Fig. 3. Variation of BSFC at different engine loads

### 3.3. $NO_X$ Emission

Fig. 4 shows the comparison of $NO_X$ emissions of dualBiodiesel and its diesel blends laden with nano particles. $NO_X$ emission in idle condition is same for standard diesel as well as the B20 dualBiodiesel (Jatropha Biodiesel – Rubber seed Biodiesel), while $NO_X$ emission for B20 is lower as compared to standard diesel at all loads which closely follows the results of tested biodiesels reported by many authors. This is due to the shorter combustion duration and higher ignition delay. This possibly allows more time for cooling inside the combustion chamber. Incidentally, Vallinayagam et al. [9] have also reported lower $NO_X$ while testing pine oil and kapok methyl ester oil. He reprted that some blends shows higher $NO_X$ emissions than conventional diesel fuel. This is due to the lower percentage of turpentine oil and the higher percentage of Jatropha biodiesel and its density. It was also observed by Ozsezen et al. [32] that an increase in fuel density results in higher $NO_X$ emissions. The dual fuel blends recommended that the optimum $NO_X$ level for 75% load condition and that may be favourable in a trade-off between $NO_X$ and BSFC with little brake efficiency reduction which exhibits that Rubber seed Biodiesel fuel having moderate percentage of (up to 50%) is observed to provide a delicate balance between the $NO_X$ emission and fuel economy and the brake power. As the Rubber seed Biodiesel percentage increases in the dual fuel blend the $NO_X$ emission decreases and BSFC also decreases. This also substantiated by Karthikeyan et al. [6] who suggested that 50% turpentine oil closely follow the trends of diesel fuel, however, for turpentine oil percentage greater than 50% renders the combustion abnormal. After the point of trade-off, the $NO_X$ emission decreases and the BSFC increases till the full load. B20 reveals the optimum results for both the condition for lower $NO_X$ and lower BSFC than all the dualBiodiesel and diesel blends laden with nanoparticles and pure diesel.However, D100Al40 has lower NOx emissions compared to dualBiodiesel and its diesel blends laden with nano particles and pure diesel.

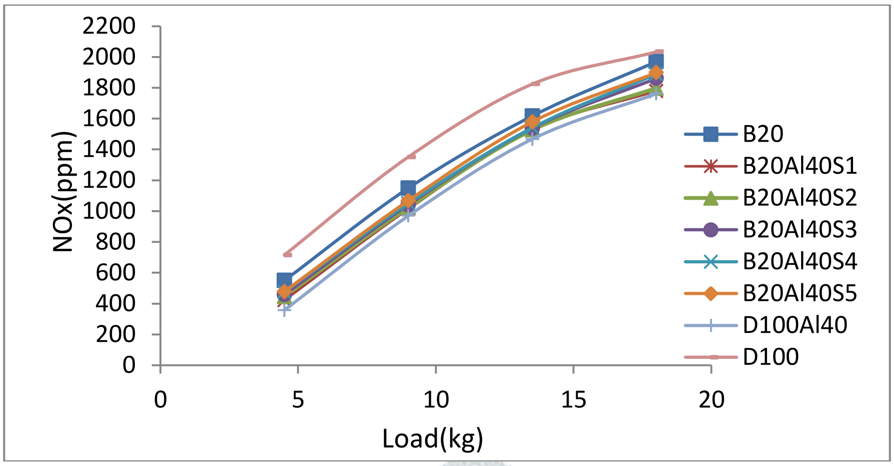


Fig.4. $NO_x$ emissions at different engine loads

### 3.4. CO Emission

The CO emission of the dual fuel blend and pure diesel fuel are shown in Fig. 5 for various load conditions (no load, 2 5 %, 50%, 75% and full load). Carbon monoxide is generally formed when there is insufficient oxygen to burn the fuel. Diesel engines generally work in excess air; therefore, diesel engines produce lower CO emissions than petrol engines [30]. It can be observed from Fig. 5 that CO emission in g/kWh decreases with increasing brake power. dualBiodiesel and its blends with nanoparticles were found to produce much lower CO emission as compared to conventional diesel fuel,at full load due to the availability of excess $O_2$ and complete combustion of the dual fuel blends. The CO emission for diesel, B20 , B20Al40S1, B20Al40S2, B20Al40S3, B20Al40S4 , B20Al40S5 and D100Al40 full load condition has observed to be 0.25,0.1, 0.15, 0.14, 0.2,0.14,0.14 and 0.14 respectively. This results were supported by Sharma et al. [33] who reported lower CO emissions when tested Jatropha biodiesel and tyre pyrolysis oil in single cylinder diesel engine compared to pure diesel.

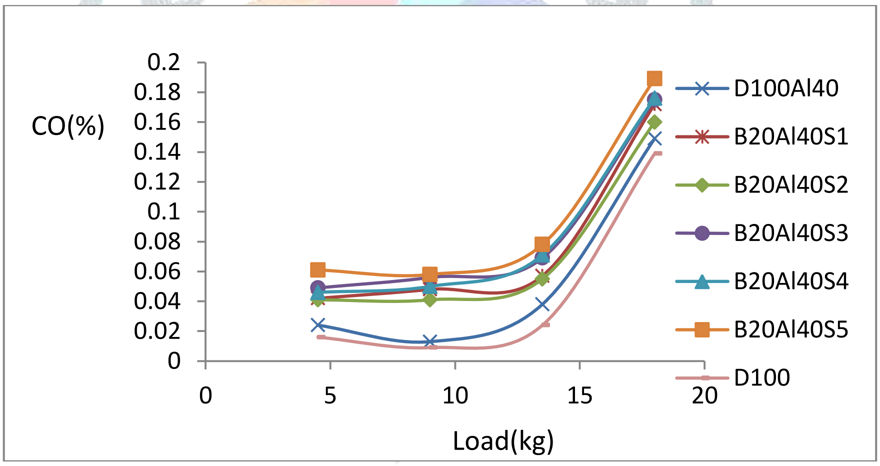


Fig. 5. CO emissions at different engine loads

### 3.5. HC Emission

Unburned hydrocarbons (HC) emissions are the hydrocarbons emitted after combustion of petroleum fuel in an engine. Fig. 6 presents HC emissions of standard diesel and dualBiodiesel and its blends tested on a single cylinder, constant speed (1500 RPM) diesel engine. dualBiodiesel and its blends with nanoparticles exhibit lower HC emissions at all load conditions than pure diesel fuel. This may be because of the density of the dualBiodiesel and its blends with nanoparticles that affects the spray entrenchment. Moreover, at low loads, the cooling effect of the charge played a significant role due to lower combustion temperatures. However, at higher loads, the difference between HC emissions emanating from dualBiodiesel is more compared to its blends with nanoparticles and that from the standard diesel fuel is smaller due to complete combustion. D100Al40 shows lower HC emissions at all load condition than dualBiodiesel and all other blends with nanoparticles tested. This results were supported by Bhupendra et al. [1] who investigated the Jatropha biodiesel and its blends with diesel fuel on the diesel engine and resulted in lower HC emissions.

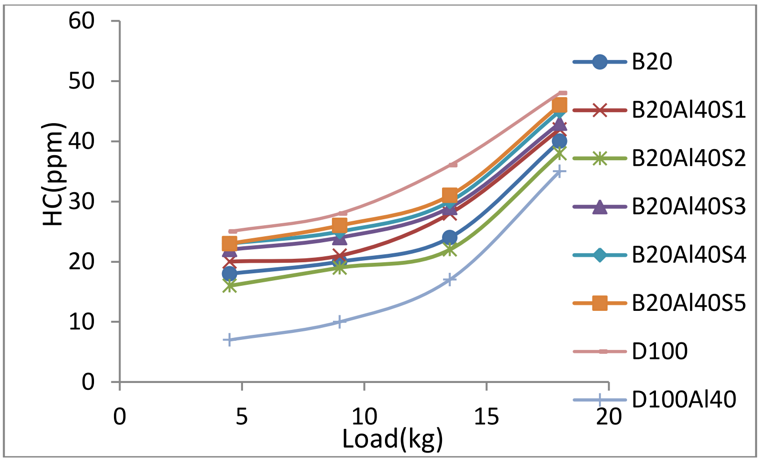


Fig. 6. HC emissions at different engine loads

**3.6. Smoke Emission**

Fig. 7 shows the smoke emission measurement for standard diesel and dual fuel blend. Smoke emission is found lower for dual fuel blends as compared to conventional diesel fuel at all loads for which test was carried out. It can be deduced from Fig. 7 that smoke emission decreases with the increase of load for dualBiodiesel,and most of its blends with nanoparticles and pure diesel. Further, it can also be inferred that smoke emission emanating from dual fuel blend is higher in case of Jatropha biodiesel but it is lower in case of conventional diesel. The dualBiodiesel exhibit lower smoke at part load than its blends with nanoparticles and pure diesel. It is due to oxygen content in the Jatropha biodiesel and higher cetane rating. This results were supported by Bhupendra et al. [1] who examined the Jatropha biodiesel and its blends with conventional diesel on the diesel engine and resulted in lower smoke emissions.

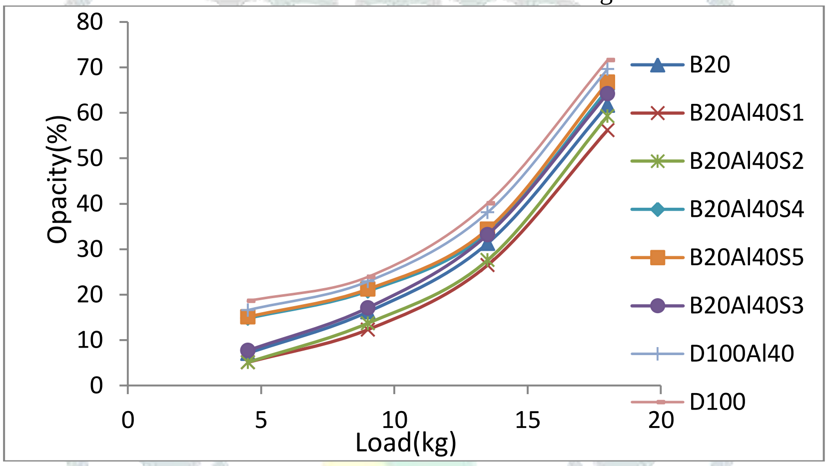


Fig. 7. Smoke opacity emissions at different engine loads

IV. CONCLUSIONS

In this work a dualBiodiesel and diesel blend, Jatropha biodiesel and rubber seed biodiesel combination is used in a diesel engine on cost basis, to eliminate the use of standard diesel to some extent and without any modification to diesel engine. In this work, the properties of both biofuels are acceptable and favourable to use in the diesel engine. The dualBiodiesel and diesel blends were investigated and combustion, performance and emission characteristics of the engine are compared with Pure diesel and D100Al40. The important points are as follows.

1. By the use of Alumina nano particle laden dualBiodiesel and diesel blends ( B20Al40S1, B20Al40S2, B20Al40S3, B20Al40S4 and B20Al40S5), the engine operated successfully & smoothly and performed better; the BTE is slightly higher for B20Al40S2 blend as compared to B20 and pure diesel.
2. Irrespective of the load conditions dual Biodiesel blend with diesel laden with nano additives, B20Al40S2 blend gives similar results in case of $CO_2$, CO, HC and smoke emission as compared to B20Al40 blend . Moreover, at full load condition, $NO_X$ emission decreases by 15% when compared to both B20, B20Al40 blends and pure diesel .
3. Rubber seed methyl ester has higher volatility and higher viscosity compared to Jatropha methyl ester, which might have caused proper mixing and complete combustion for Jatropha methyl ester and micro explosion caused by nano additives ; also the nanofluid stability increase with the use of Surfactant, therefore, Alumina nano particle laden dualBiodiesel and diesel blend with nano additives and Surfactant shows higher performance and closer emissions to B20,D100Al40 blends and pure diesel.

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NOMENCLATURE

BSFC: Brake specific fuel consumption
RSBD: Rubber Seed Bio Diesel
JBD : Jatropha Bio Diesel
PPM: Parts Per Million
B20: Dual Biodiesel blend (80% Pure diesel,10% Jatropha Methyl Ester , 10% Rubber seed Methyl Ester)
B20Al20: Dual Biodiesel blend (80% Pure diesel,10% Jatropha Methyl Ester , 10% Rubber seed Methyl Ester and 20 ppm $Al_2O_3$ Nano particles)
B20Al40: Dual Biodiesel blend (80% Pure diesel,10% Jatropha Methyl Ester , 10% Rubber seed Methyl Ester and 40 ppm $Al_2O_3$ Nano particles)
B20Al60: Dual Biodiesel blend (80% Pure diesel,10% Jatropha Methyl Ester , 10% Rubber seed Methyl Ester and 60 ppm $Al_2O_3$ Nano particles)
B20Al80: Dual Biodiesel blend (80% Pure diesel,10% Jatropha Methyl Ester , 10% Rubber seed Methyl Ester and 80 ppm $Al_2O_3$ Nano particles)
B20Al100: Dual Biodiesel blend (80% Pure diesel,10% Jatropha Methyl Ester , 10% Rubber seed Methyl Ester and 100 ppm $Al_2O_3$ Nano particles)
BSFC: Brake specific fuel consumption
BTH: Brake thermal efficiency
CO: Carbon mono oxide
$CO_2$: Carbon dioxide
DI: Direct injection
HC: Hydro carbon
NOx: Nitrogen oxides
kW: Kilo watt
% vol: Percentage volume
cc: cubic centimetre
PD: pure diesel
deg: Degree
CA: crank angle
1-Cylinder: Single cylinder