Scientific Journal of Impact Factor (SJIF): 3.134

E-ISSN (O): 2348-4470
P-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2, Issue 12, December -2015

Influence of Crude Sunflower oil on Performance and Emission Characteristics of Diesel Engine during Short Term Test

Pinkesh R. Shah[1]

[1]*Mechanical Department, Government Polytechnic, Ahmedabad*

Abstract —*Due to the worldwide effort to make renewable energy economically viable as well as to use cleaner fuels, SVO (Straight Vegetable oil) can become an indispensable tool in global trade. Different types of vegetable oil are grown locally and one way to use is to convert this vegetable oil into biodiesel but this conversion technique is not available or accessible in remote and rural areas due to economical constraints. So use of locally available crude vegetable oil in existing diesel engine without any modifications becomes an interesting option if performance, emission and maintenance of an engine are comparable to diesel fuel. The results of the literature review have indicated that a performance and emission characteristic of DI diesel engine fuelled with crude Sunflower oil is not investigated. Therefore, the main purpose of the research is to evaluate the effectiveness of commercially available Sunflower oil on the Performance and Emission characteristics of diesel Engine. This paper intends to compare the performance and emission characteristics of diesel and Sunflower oil based on short term experimental results carried out on Cummins two cylinder DI engine by varying brake load at constant speed. This study also shed light on comparison of physical properties of diesel and Sunflower oil and correlates them with the test results. The test results showed that physical properties like density, viscosity, surface tension and flash point of crude Sunflower oil were found higher whereas calorific value was lower than diesel fuel. The Sunflower oil emitted lower NO_x emissions and higher CO emission as compared to diesel at lower load condition while the opposite trend was observed at full load condition i.e. higher NO_x emissions and lower CO emission as compared to diesel fuel. The Sunflower oil significantly increased brake thermal efficiency at full load whereas reduced thermal efficiency at part load as compared to diesel fuel. However, Sunflower oil was producing quite lower smoke emission than diesel throughout the load range. Thus, crude Sunflower oil performed better at full load than at part load based on performance and emission characteristics of diesel engine during short term load test.*

Keywords*- straight vegetable oil; Sunflower oil; diesel engine; performance characteristics; emission characteristics*

I. INTRODUCTION

Unlike the rest of the world, India's demand for diesel fuels is roughly six times than that of gasoline so diesel fuels play an important role in the industrial economy of a country. These fuels run a major part of the transport and industrial sector and their demand is increasing steadily. Besides increased financial expenses, population year by year confronts growing ecological problems which requiring an alternative fuel which is technically feasible, economically competitive, environmentally acceptable, and readily available [1]**.** In the last three decades, global energy crisis and the increasingly stringent emission norms have triggered various research studies to replace petroleum based diesel fuel with the vegetable oils or their derivations because straight vegetable oil (SVO) made from agricultural products (oxygenated by nature) reduce the world's dependence on oil imports, support local agricultural industries and enhance farming incomes and, moreover, offer benefits in terms of usually reduced emissions [2].

There are many publications reported in the literature about use of vegetable oil with blend with diesel fuel. An experimental study was conducted by D.C. Rakopoulos et al. [3] to evaluate the use of Sunflower, cottonseed, corn and olive straight vegetable oils of Greek origin, in blends with diesel fuel and test results showed that vegetable oil blends reduced emitted smoke with slight increase of NO_x emissions and effectively unaffected thermal efficiency as compared to diesel. M. S. Shehata et al. [4] performed the experiments with blend of Jojoba and Sunflower oil with diesel and showed lower brake thermal efficiency and NO_x emissions whereas higher CO emission. Similarly, combustion and emission characteristics of Rapeseed plant oil blends with diesel fuel was investigated by L. Labecki et al. [5] in multi cylinder direct injection diesel engine to lower the NO_x emissions by varying the injection parameter. A. Agarwal et al. [6] also performed the experiment by blending Karanj oil and diesel in different proportions to evaluate the performance and emission characteristics of diesel engine. However, the vegetable oil can be effectively used worldwide by converting into bio-diesel [7-8] but chemical process to prepare biodiesel is not easily accessible in remote and rural area due to logistic problems and expenses.

There are many publications reported in the literature about use of vegetable oil by blending with diesel or convert into bio-diesel but very little publications available concern with direct use of crude vegetable oil. Thus, crude vegetable oils are receiving increasing public and scientific attention to use in diesel engine. These natural crude vegetable oils called as Straight Vegetable Oils (SVOs) are simply filtered oil have great potential for commercial exploitation and utilize them as fuels in diesel engine in recent year. Due to the glycerides present in the oils, vegetable oils have been found to be a potential alternative to diesel. They have properties comparable to diesel and can be used to run a diesel engine without any modifications.

The use of vegetable oils will also reduce the net CO_2 emissions. Due to its complex structure and composition, combustion duration and ignition delay increased with vegetable oils as compared to diesel [9]. There are many types of vegetable oil like Canola, Soybean, Peanut, Sunflower, Palm, Coconut oil, Jatropha Curcas, Mahua, Neem, Karanj, Kusum, babassu, Rubber seed, Jojoba oil, etc. among the 350 oil bearing crops identified. Some engine researchers [10-11] find that use of straight vegetable oil in DI diesel engine delivers approximately the same maximum power with slightly higher specific fuel consumption and reported high value of particulate matter, CO, NO_x and HC emissions as compared to diesel fuel but choking of injector tip is a major problem while using over an extended period of time.

The main objective of present study is to investigate the influence of crude Sunflower oil on performance and emission characteristics of multi cylinder unmodified diesel engine by varying brake load at constant speed and compare the test results with base line diesel fuel. It also focuses on measurement of physical properties of test fuels and correlates them with test results.

II. EXPERIMENTAL SET-UP AND TEST PROCEDURE

Owing to the differences among the lower calorific values and oxygen contents of the fuels tested, the comparison must be affected at the same engine brake load, and not at the same injected fuel mass or air–fuel ratio.

2.1. Engine Description

Facilities to monitor and control engine variables such as engine speed, load, water and lube-oil temperatures, fuel and air flows, etc. are installed on a fully automated computerized test bed, twin cylinder, four-stroke, water cooled, Cummins DXP 15-5 series Diesel Genset. All tests were performed at the standard injection pressure of 210 bar and injection advances at 11^{o} BTDC. The detail specifications of an engine are shown in table 1.

Table 1: Engine Specification

Engine Make	Cummins
Model	X 1.7 G1
BHP	20
No. of cylinders	02
RPM	1500
Bore (mm)	91.44
Stroke (mm)	127
Compression ratio	18.5:1
Displacement (liter)	1.7
Governor	Mechanical

2.2. Test Set-up Description

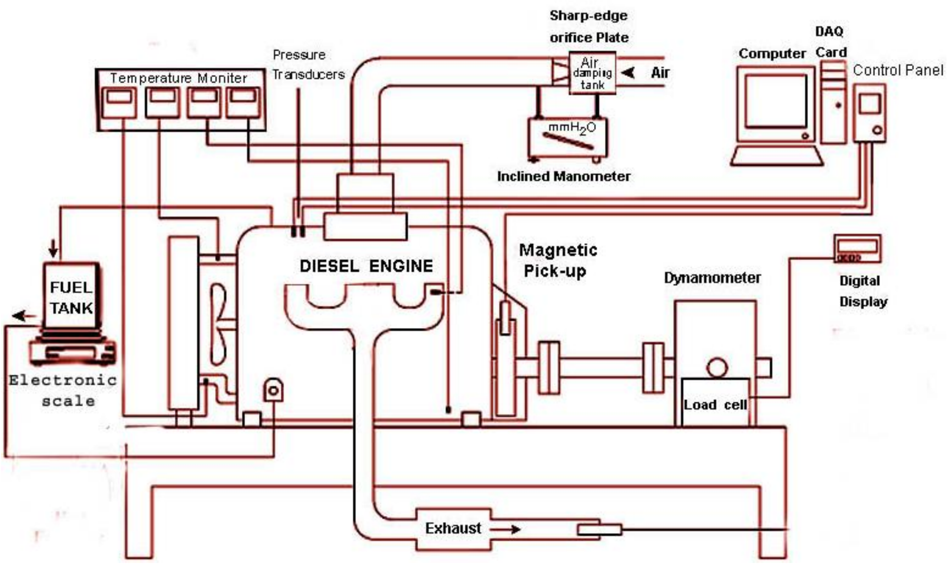

Figure 1: Schematic Diagram of Experimental Set up

The Figure 1 shows the schematic diagram of experimental set-up. The engine is mounted on a fully automated test bed and coupled to an alternator having load absorbing and motoring capabilities through heating coil load bank. There is one electric sensor for speed and one for load (torque), with these signals fed to indicators on the control panel and to the controller via knobs on the control panel, the operator can set the dynamometer to control speed or load. Electrically driven pumps assure the coolant and lube-oil circulation, with the temperature controlled by thermocouple sensor. K-type thermocouples are located at strategic points in the engine, with their indications shown on a multi-point electronic temperature indicator. The engine exhaust system is connected to a shop made silencer system. A viscous type, air box method is used for measuring the airflow aspirated by the engine.

2.3. Test Fuels Characterization

Among vegetable oils, Sunflower oil was chosen after comparing properties of various oils. The raw Sunflower oil was obtained from local commercial supplier at Mumbai in India. The commercial neat diesel fuel used in the tests is obtained locally from the Petrol pump. The properties measured at room temperature for comparison of Sunfloer oil and diesel fuel used in this study is given in Table 3. The elemental analysis was carried out at Sophisticated Analytical Instruments Facility center, IIT Bombay.

Table 2: Physical Properties Measured for Test Fuels

Properties	**Diesel**	**Sunflower oil**
Density (kg/m^3)	807	889
Viscosity (cst)	3.16	67
Calorific value (MJ/kg)	43.75	38.95
Surface Tension (mN/m)	27.12	33.01
Flash Point (^{o}C)	93	274
Elemental Analysis		
Carbon (%)	85.30	78.76
Hydrogen (%)	15.47	10.06
Nitrogen (%)	1.74	0.88
Oxygen (%)	-	9.34

2.4. Parameters Measured and Experimental Procedure

The engine was equipped with an orifice meter connected to an inclined manometer to measure mass flow rate of the intake air. An air damping tank was used for damping out the pulsations produced by the engine, thus obtaining a steady air flow. The fuel consumption was determined by weighing fuel used for a period of time on an electronic scale. In each test, exhaust gas temperature is also measured. From the first measurement, Brake Specific Energy Consumption (BSEC) and brake thermal efficiency (BT) are computed using the fuel density and lower calorific value of fuels. The Gas analyzer (Make: Quintox, India. Model: kane) was used to measure exhaust emissions of CO and NO_x emissions while smoke opacity was measured in Bosch Smoke unit in BSN (Bosch Smoke Number). The intensity of smoke on filter paper was matched with the standard chart rated in the scale 0-10.

The fuels were tested in order as petroleum diesel followed by crude Sunflower oil and the readings were taken at various load such as 0%, 25%, 50%, 75% and full load i.e. from no load to full load and reverse from full load to no load. Thus, total 9 test points for each test fuel were examined and at each of the 9 test points, 2 snapshots of the engine operating parameters were taken and thus each test was repeated 2 times. The results of repetitions were averaged to decrease the uncertainty. The tests were performed at steady state conditions. Exhaust temperature was taken as an indication of stability and the readings at any given test point were taken only after the exhaust temperature stabilized.

III. RESULTS AND DISCUSSION

The test results are discussed for each parameter of performance and emission characteristics of diesel engine by comparing crude Sunflower oil with base diesel fuel.

3.1. Performance Characteristics

The brake specific energy consumption and brake thermal efficiency parameters are discussed in performance characteristics.

3.1.1. BSEC (Brake Specific Energy Consumption)

In this study, BSEC is considered instead of BSFC due to variation in Calorific Value of fuel used.

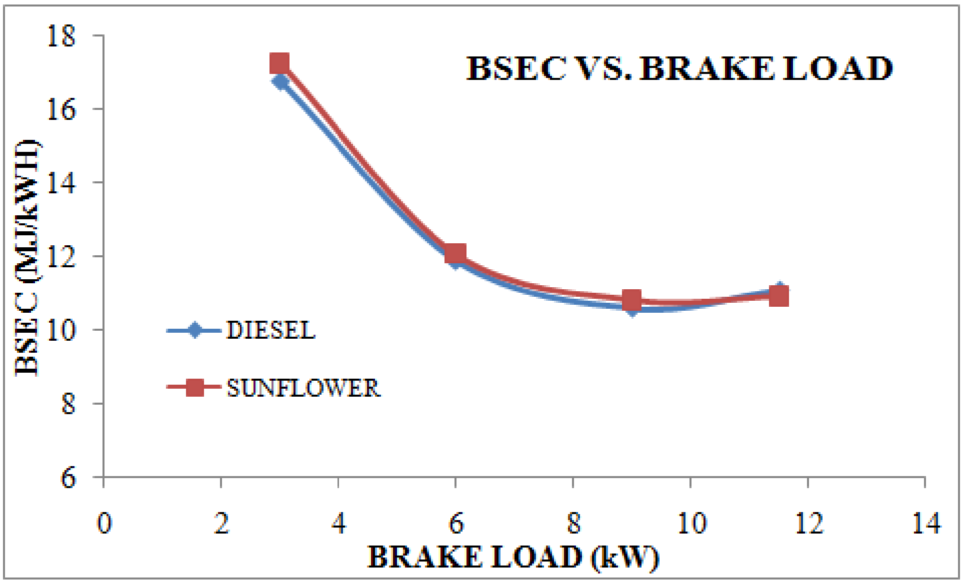

Figure 2: Variation of BSEC with Brake Load

Figure 2 shows the brake specific energy consumption (BSEC) with brake load for Sunflower oil and diesel fuel. It is seen that BSEC is slightly lower for Sunflower oil at full load and is higher at lower load than that of diesel fuel. At full load the BSEC for Sunflower oil is 10.91 MJ/kWh as compared to 11.11 MJ/kWh for diesel fuel whereas at low load the BSEC is 17.25 MJ/kWh for Sunflower oil as compared to 16.78 MJ/kWh for diesel fuel. Two factors are considered to explain the behavior. One is the lower heating value of the Sunflower oil which requires more fuel to be injected into the cylinder to get the same power output, leading to the increase in the BSEC. Second is the enhancement of the premixed combustion duration and diffusive combustion duration, owing to the prolonging of ignition delay and increases the amount of fuel burned in the premixed burning phase, causing a high cylinder pressure rise and reducing the BSEC value. The comprehensive influence makes the increase of BSEC at lower load condition. The higher the engine load is, the higher is the gas temperature in the cylinder, and hence, the better are the fuel rich mixture burning conditions leads to lower BSEC [12].

3.1.2. BTE (Brake Thermal Efficiency)

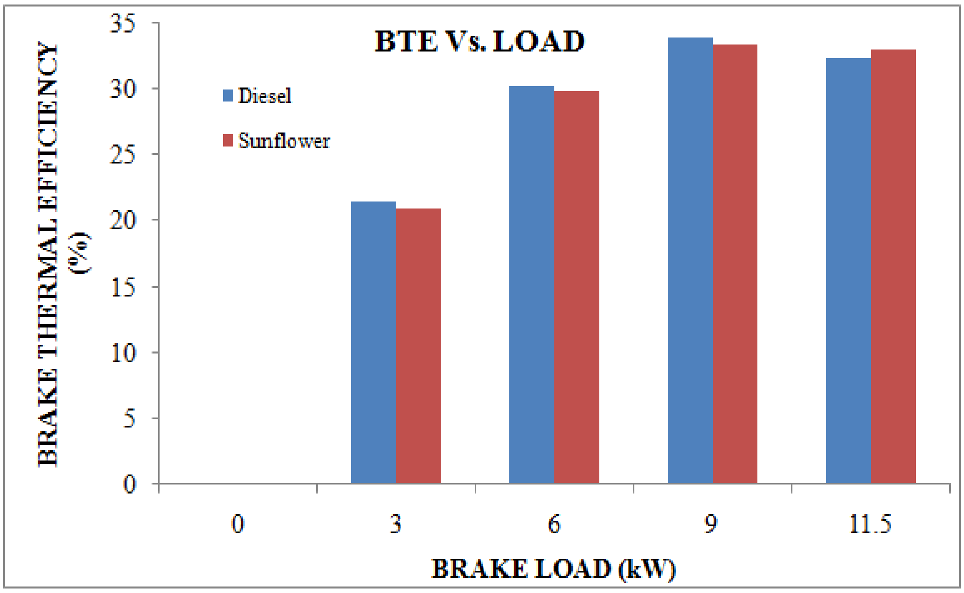

Figure 3: Variation of Brake Thermal Efficiency with Brake Load

Figure 3 shows the brake thermal efficiency (BTE) with brake load for Sunflower oil and diesel fuel. It can be seen that brake thermal efficiency of Sunflower oil is found lower than diesel fuel at lower and middle load condition however the improvement occurs more significantly at higher load condition. It can be seen that Sunflower oil shows 2% higher thermal efficiency than diesel fuel at full load condition whereas 1.8% lower BTE than diesel at lower load condition. At low and middle engine loads, there is almost no fuel-rich zone because of the higher excess air/fuel ratio, and the lean fuel/ air mixture and poor ignitibility always lead to incomplete combustion. So, oxygen contents in Sunflower oil play a moderate effect on the combustion efficiency at low engine load. The improvement of brake thermal efficiency at full load can be attributed to the promoted combustion in the fuel-rich zone due to the oxygen content (Table-2) of vegetable oil which leads to the fuel/air mixture becoming more homogeneous. As a result, the combustion efficiency was enhanced [13]. Also at higher load, high cylinder temperatures occurred which improve vaporization and mixing process of fuel and air, thus leading to a shortened ignition delay and higher combustion efficiency [14].

3.2. Emission Characteristics

The oxides of nitrogen, carbon monoxide and smoke opacity parameters are discussed in emission characteristics.

3.2.1. NO_x emissions

The most troublesome emissions from diesel engines are NO_x emissions. The oxides of nitrogen in the exhaust emissions contain nitric oxide (NO) and nitrogen dioxides (NO_2). The formation of NO_x is highly dependent on in-cylinder temperatures, the oxygen concentration and residence time for the reaction to take place. Thermal NO_x formation is the main contributor to NO_x emissions from a diesel engine [15].

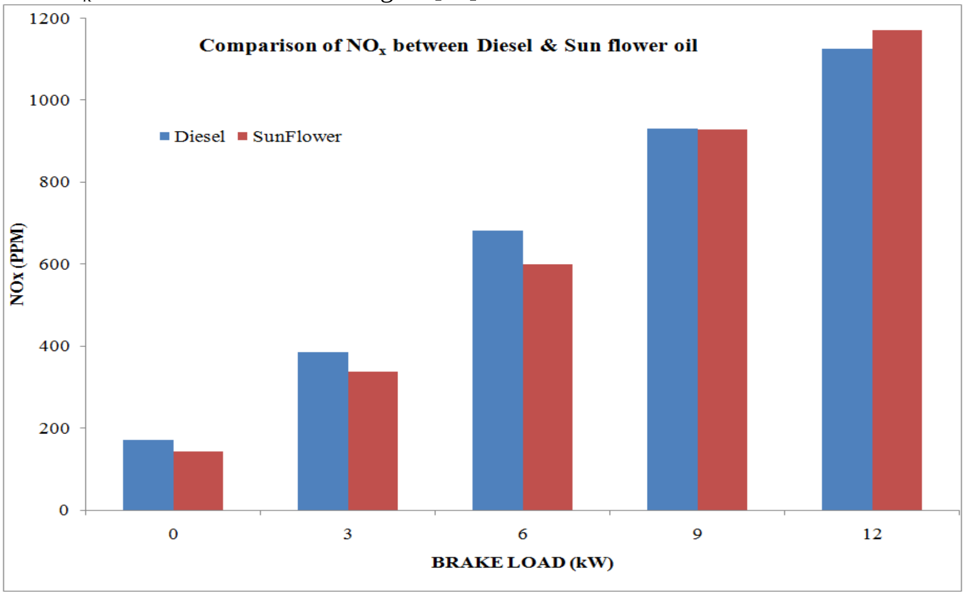

Figure 4: Variation of NO_x emissions with brake load

Figure 4 shows the comparison of oxides of nitrogen (NO_x) emissions between diesel and Sunflower oil. It can be seen that Sunflower oil shows 10% - 15% lower NO_x emissions than diesel up to middle load conditions due to its lower calorific value and higher flash point (Table-2) which in turn lowers the peak combustion temperature due to poor volatility of fuel. Since the NO_x concentration rises with the higher brake power values due to increased gas cylinder temperatures. The Sunflower oil shows 4% higher NO_x than diesel at full load condition due to the presence of oxygen in the oil (Elemental analysis) leading to enhancing the combustion resulting in higher combustion temperature. While oxygenated fuels have a lower adiabatic flame temperature, the soot particles are good heat absorbers. The reduction in soot particles contributes to increase gas temperature and consequently increases NO_X emissions. It should also be noted that most vegetable oils contain small quantities of nitrogen containing proteins. This small amount of nitrogen in addition to atmospheric nitrogen releases extra NO_x emissions through combustion. This might be a contributing factor for Sunflower oil to have higher NO_x emissions than diesel fuel [16]. The reason for NO_X decreasing or increasing with crude Sunflower oil is still under debate.

3.2.2. CO emissions

The CO emissions in the exhaust gases represent lost chemical energy that is not fully utilized in the engine. The major contributor to CO formation is insufficient time and oxygen for the oxidation of CO to CO_2. The CO is formed when the engine is being operated on too rich fuel air ratio and there is insufficient oxygen for complete combustion.

In comparison to diesel operating conditions, CO emission is higher than that of diesel at lower and middle-load conditions whereas lower than that of diesel at higher load conditions as shown in Figure 5. From the test results it is seen that Sunflower oil shows 15% - 30% higher CO emission than diesel at lower and middle-load conditions due to its higher viscosity (Table-2). Higher viscosity causes difficulty in atomization of droplet inside the combustion chamber leading to reduction in spray cone angle and less air entrainment and thus poor mixture formation resulting in poor spray characteristics forming locally rich air-fuel mixtures during the combustion process leading to incomplete combustion and CO formation. In addition, lack of oxygen locally at lower load conditions lead to lower combustion temperature because of poor mixing causes more carbon monoxide emission. On the other hand, Sunflower oil shows 17.2% lower CO emission than diesel fuel at full load due to improved atomization rate with rising temperature at full load resulting in complete combustion in addition to the fact that the oxygen present (Table-2) in the Sunflower oil supports the combustion process thereby reducing carbon monoxide emission. This result is also in accordance with lower smoke opacity and higher thermal efficiency at full load.

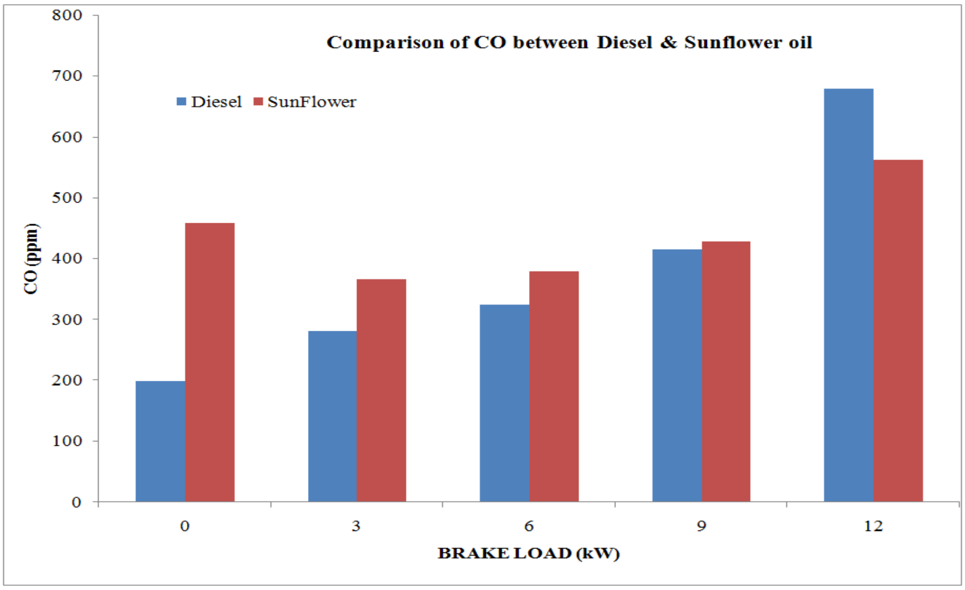

Figure 5: Variation of CO emission with brake load

3.2.2. Smoke opacity

Opacity is the degree to which smoke blocks the light and smoke formation strongly influenced by diffusive combustion duration as well as the compositions of hydrocarbons in the fuel.

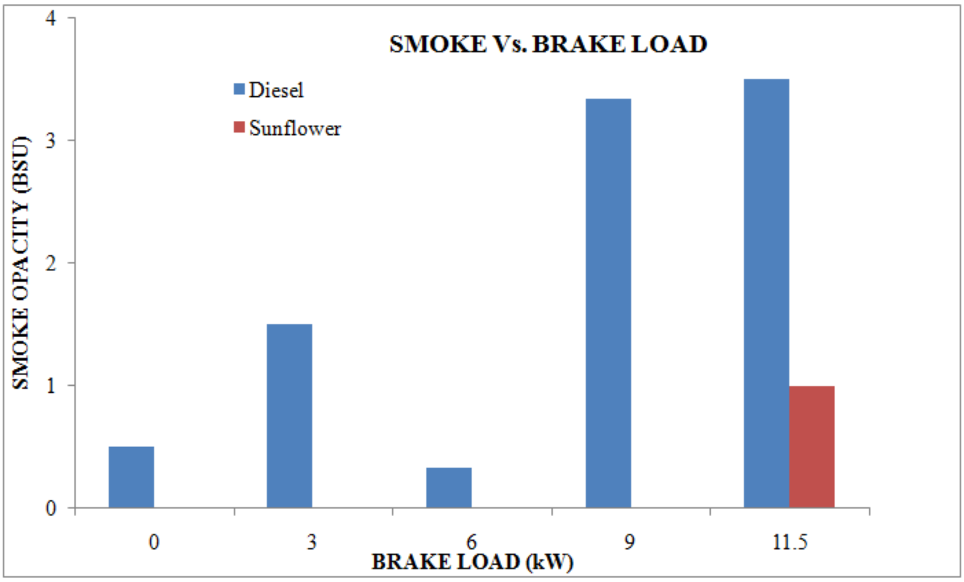

Figure 6: Variation of smoke opacity with brake load

Figure 6 represents the comparison of Smoke opacity between diesel and Sunflower oil with brake load. It can be seen that negligible amount of smoke is produced for Sunflower oil at lower load which was not measurable within the consistency of our equipment. It is found that Sunflower oil exhibits 70% lower smoke emission than diesel fuel at full load. The probable reason can be assigned due to the presence of oxygen (Elemental analysis) in the structure of Sunflower oil makes the mixture leaner thereby the combustion being now assisted by the presence of fuel-bound oxygen even in locally rich zones resulting in lower smoke opacity. This effect may be offset by high viscosity and density of fuel [17].

IV. CONCLUSION

The main conclusions can be summarized on the basis of experimental results are as follows:

1. The physical properties such as density, viscosity, surface tension and flash point are found higher for Sunflower oil than diesel whereas calorific value is found lower than diesel fuel.
2. The Sunflower oil shows 1% - 3% higher BSEC than diesel at lower load whereas 1.7 % lower BSEC than diesel fuel at full load condition. Similar trend is observed for brake thermal efficiency i.e. lower BTE at lower load and higher BTE at higher load as compared to diesel fuel.
3. Sunflower oil shows 10% - 15% lower NO_x emissions than diesel up to middle load conditions due to its lower calorific value and higher flash point whereas 4% higher NO_x emissions than diesel at full load condition due to the presence of oxygen in its structure.
4. Sunflower oil shows 15% - 30% higher CO emission than diesel at lower and middle-load conditions due to its higher viscosity whereas 17.2% lower CO emission than diesel fuel at full load due to improved atomization rate with rising temperature at full load.
5. Sunflower oil emits 70% lower smoke emission than diesel fuel at full load.

The test results revealed that crude Sunflower oil can be effectively used in diesel engine without any modifications at full load rather than at part load during short term performance test. Hence, utilization of crude Sunflower oil as an alternate fuel is an attractive option in rural and remote areas of developing countries like India in decentralized power generation, where grid power is not available.

Acknowledgement
The authors wish to express their deep thanks to the management of Cummins India Engine Research Centre, Pune, India for providing facility and necessary funding to carry out the experiments. I wish to express my sincere thanks to Mr. Gajanan Dandekar for his expertise and technical support in conducting the experiments. I am also grateful to SAIF, IIT Bombay for providing testing facility.

REFERENCES

[1] S. Dmytryshyn, a. Dalai, S. Chaudhari, H. Mishra, and M. Reaney, “Synthesis and characterization of vegetable oil derived esters: evaluation for their diesel additive properties,” *Bioresour. Technol.*, vol. 92, no. 1, pp. 55–64, Mar. 2004.

[2] C. Rakopoulos, K. Antonopoulos, D. Rakopoulos, D. Hountalas, and E. Giakoumis, “Comparative performance and emissions study of a direct injection Diesel engine using blends of Diesel fuel with vegetable oils or bio-diesels of various origins,” *Energy Convers. Manag.*, vol. 47, no. 18–19, pp. 3272–3287, Nov. 2006.

[3] D. C. Rakopoulos, C. D. Rakopoulos, E. G. Giakoumis, A. M. Dimaratos, and M. A. Founti, “Comparative environmental behavior of bus engine operating on blends of diesel fuel with four straight vegetable oils of Greek origin: Sunflower, cottonseed, corn and olive,” *Fuel*, vol. 90, no. 11, pp. 3439–3446, Nov. 2011.

[4] M. S. Shehata and S. M. A. Razek, “Experimental investigation of diesel engine performance and emission characteristics using jojoba/diesel blend and sunflower oil,” *Fuel*, vol. 90, no. 2, pp. 886–897, Feb. 2011.

[5] L. Labecki, a. Cairns, J. Xia, a. Megaritis, H. Zhao, and L. C. Ganippa, “Combustion and emission of rapeseed oil blends in diesel engine,” *Appl. Energy*, vol. 95, pp. 139–146, Jul. 2012.

[6] A. K. Agarwal and K. Rajamanoharan, “Experimental investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel engine,” *Appl. Energy*, vol. 86, no. 1, pp. 106–112, Jan. 2009.

[7] A. S. Ramadhas, C. Muraleedharan, and S. Jayaraj, “Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil,” *Renew. Energy*, vol. 30, no. 12, pp. 1789–1800, Oct. 2005.

[8] P. McCarthy, M. G. Rasul, and S. Moazzem, “Analysis and comparison of performance and emissions of an internal combustion engine fuelled with petroleum diesel and different bio-diesels,” *Fuel*, vol. 90, no. 6, pp. 2147–2157, Jun. 2011.

[9] K. Purushothaman and G. Nagarajan, “Performance, emission and combustion characteristics of a compression ignition engine operating on neat orange oil,” *Renew. Energy*, vol. 34, no. 1, pp. 242–245, Jan. 2009.

[10] M. K. Abbass, G. E. Andrews, and P. T. Williams, “The Composition of the Organic Fraction of Particulate Emissions of a Diesel Engine Operated on Vegetable Oil,” *SAE Tech. Pap.*, vol. 901563, pp. 1–16, 1990.

[11] N. Nabi, S. Rahman, and R. A. Beg, “Fundamental Properties of Different Vegetable Oils Available in Bangladesh,” *SAE Tech. Pap.*, vol. 2003–01–31, pp. 1–11, 2003.

[12] Y. Ren, Z. Huang, H. Miao, Y. Di, D. Jiang, K. Zeng, B. Liu, and X. Wang, “Combustion and emissions of a DI diesel engine fuelled with diesel-oxygenate blends,” *Fuel*, vol. 87, no. 12, pp. 2691–2697, Sep. 2008.

[13] X. Lü, J. Yang, W. Zhang, and Z. Huang, “Improving the Combustion and Emissions of Direct Injection Compression Ignition Engines Using Oxygenated Fuel Additives Combined with a Cetane Number Improver,” *Energy & Fuels*, vol. 19, no. 5, pp. 1879–1888, Sep. 2005.

[14] M. Karabektas and M. Hosoz, “Performance and emission characteristics of a diesel engine using isobutanol–diesel fuel blends,” *Renew. Energy*, vol. 34, no. 6, pp. 1554–1559, Jun. 2009.

[15] E. İleri and G. Koçar, “Effects of antioxidant additives on engine performance and exhaust emissions of a diesel engine fueled with canola oil methyl ester–diesel blend,” *Energy Convers. Manag.*, vol. 76, no. x, pp. 145–154, Dec. 2013.

[16] N. Yilmaz and B. Morton, “Effects of preheating vegetable oils on performance and emission characteristics of two diesel engines,” *Biomass and Bioenergy*, vol. 35, no. 5, pp. 2028–2033, May 2011.

[17] B. Singh, N. Kumar, Y. Du, and K. Bae, “Performance and emission study of preheated Jatropha oil on medium capacity diesel engine,” *Energy*, vol. 35, no. 6, pp. 2484–2492, 2010.

