Performance and Emission Characteristics of Waste Cooking Oil Biodiesel and EHN as Additive in Single Cylinder Diesel Engine

Dr. Supriya Bobade, Prof. R. D. Gadve, Hrushikesh Turakane, Rakesh Bhol,

Shubham Waghole, Mangesh Thadkar.

ABSTRACT:-**Now a days due to development in all areas and increase in demand of fossil fuels from automobile sector, it is necessary to find another sources of energy. Fossil fuel is the main source of energy. Biodiesel prepared from waste cooking oil is the best replacement for the fossil fuels. In this study biodiesel was prepared from waste cooking oil by trans-esterification process. This biodiesel mixes with conventional diesel in volume percentages 6, 12, 18, 24, 30, 36 as B06, B12, B18, B24, B30, B36 along with constant 5% EHN as an additive. Prepared biodiesel blends were tested in single cylinder four stroke diesel engine at constant engine speed of 1500 rpm and compression ratio maintained at 16:1. The results of experiments shows increase in brake power and brake thermal efficiency with load for all the blends. The brake specific fuel consumption decreases with increase in load. CO, HC emissions for waste cooking oil biodiesel blends were lower than diesel oil. NO_x emissions for biodiesel blends were higher than diesel fuel.**

Keywords **:- Waste cooking oil, Biodiesel, EHN, Performance, Emission.**

1. Introduction

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal fats, beef tallow, plastic and waste cooking oil. All this oil converted into biodiesel by using trans-esterification process [1]. At present, most biodiesel is produced from waste cooking oil sourced from restaurants, industrial food producers etc. The raw oil from the agricultural industry shows a great potential to convert it into biodiesel. It is not being produced commercially simply because the raw oil is too expensive and it does not compete with the present cost of conventional diesel. Waste cooking oil can be obtained at a less price. The results obtained from this waste cooking oil biodiesel and EHN as an additive are almost superior than fossil diesel. Biodiesel is a domestically produced, clean-burning, renewable substitute for petroleum diesel. Biodiesel burns significantly cleaner than regular petroleum diesel [2].

It is noticed from the literature review that, Muralidharan and Vasudevan investigated performance, emission and combustion characteristics of single cylinder diesel engine when fueled with 20%, 40%, 60% and 80% waste cooking oil biodiesel blends with diesel. The experiment conducted at a constant engine speed of 1500 rpm and at various compression ratios. From the results it is concluded that brake thermal efficiency is maximum for the B40 blend and the emission of HC, NO_x increases with the increase in compression ratio [3].

In another different study, A. Abu-Jrai et al [4], conducted a test on diesel engine when fueled with treated waste cooking oil biodiesel blends with diesel. The test was conducted on a four cylinder direct injection diesel engine at 1500 rpm of engine speed with three different engine loads 25%, 50% and 75%. It is reported that brake specific fuel consumption is more for treated biodiesel blends as compared to diesel. Due to the use of EGR technique the NO_x emission gets reduced and smoke emission increases for all the prepared blends.

In a study conducted by K. A. Abed et al [5], investigated the performance and exhaust emissions of a diesel engine with the use of waste cooking oil biodiesel blends with diesel fuel. Experimental test were conducted on a kirloskar make single cylinder direct injection diesel engine under different engine loads at an engine speed of 1500 rpm. Their results showed that the thermal efficiency is less and specific fuel consumption is more for biodiesel blends as compared with diesel. The emissions such as carbon monoxide, hydrocarbon were lower for WCO biodiesel blends.

Ozer can [6], presented the results of investigation of performance and exhaust emission of a diesel engine with the use of waste cooking oil biodiesel mixture, In this study the 5% and 10% biodiesel mixes with diesel fuel. The experimental test conducted on a single cylinder diesel engine at four different engine loads and at constant engine speed of 2200 rpm. The results of experiment reported as increment in brake specific fuel consumption up to 4%, and brake thermal efficiency reduces up to 2.8% the emission increases with the increase in biodiesel content.

In a study conducted by M. Pugazhvadivu et.al [7], Investigated the performance and exhaust emission of a diesel engine when fueled with preheated waste frying oil. Experimental test was performed on a diesel engine at a constant speed. Due to the preheating of biodiesel at about 135 ^{o}C, the viscosity of biodiesel reduces and becomes equals to the diesel fuel which results in complete combustion of the fuel and CO, HC emission were less as compared to non-preheated waste fried oil.

Nomenclature

B00	Conventional Diesel Fuel	BP	Brake power
B06	6% Biodiesel + 5% EHN +89% Diesel	BTE	Brake thermal efficiency
B12	12% Biodiesel + 5% EHN +83% Diesel	CO	Carbon monoxide
B18	18% Biodiesel + 5% EHN +77% Diesel	CR	Compression ratio
B24	24% Biodiesel + 5% EHN +71% Diesel	HC	Hydro carbon
B30	30% Biodiesel + 5% EHN +65% Diesel	NO_x	Nitrogen oxides
B36	36% Biodiesel + 5% EHN +59% Diesel	WCO	Waste cooking oil
SFC	Specific fuel consumption	EHN	Ethyl hexyl nitrate
ASTM	American society for testing and materials	^{o}C	Degree celsius

Mohamed F. Al-Dawody et. al [8], presented the experimental study on the performance and emission of diesel engine fueled with waste cooking oil methyl ester blended with diesel fuel. In this study biodiesel is mixed in the percentages of 10, 20 and 100 on a volume basis and tested on a diesel engine at a constant speed. The result of test stated that brake thermal efficiency reduces while the specific fuel consumption increases with increase in quantity of biodiesel and it is concluded that 20% of methyl ester waste cooking oil is the best mixing ratio that reduces the emission of NO_x. The earlier studies indicate that addition of EHN into diesel fuel improves ignitability and cetane number. The auto ignition temperature of diesel fuel is 383 ^{0}C, this cetane improver helps to reduce auto ignition temperature and lead to quicker combustion [9].

I. Materials and Methods

A. Biodiesel Production

In this study the waste cooking oil was collected from the restaurants, Chinese food stall is being used to produce the biodiesel with the help of trans-esterification process. First the waste cooking oil is filtered to remove the impurities and then heated up to 110 ^{0}C for two hour in order to remove the water content in it [10]. The conversion of waste cooking oil into biodiesel is completed in two stage. In first stage waste cooking oil undergone through esterification process. To conduct esterification of waste cooking oil, 1000 ml of raw waste cooking oil was poured in round bottom flask equipped with heating mantle, mechanical stirrer, thermometer and condenser. The waste cooking oil first heated up to 60 ^{0}C and 0.5% (by wt.) sulphuric acid is to be added to oil and then methyl alcohol at about 10% (by wt.) is added. The reaction of mixture was carried with stirring at 600 rpm and temperature of the mixture was controlled at 55 ^{0}C to 60 ^{0}C for 30-45 minutes. While performing reaction the care should be taken that the temperature should not exceed 65 ^{0}C otherwise the dissolved methanol gets evaporated and will result in much lesser yield. After 45 minutes the acid value of waste cooking oil falls from 18 mg KOH/gm to 4.3 mg KOH/gm. This esterified oil was fed to the second stage i.e., trans-esterification process.

In trans-esterification process a sodium methoxide solution was prepared in 250 ml beaker by mixing 5 gm of sodium hydroxide pellet into 180 ml of methanol. The solution stirred properly until the sodium hydroxide dissolved completely. After that sodium methoxide solution is mixed with earlier esterified oil at 60 ^{0}C and stirred it for next one and half hour. Finally this mixture was allowed to settle at about 8 to 10 hour in a separating funnel. In this settling period glycerol is settled at bottom of a funnel and unpured biodiesel at the top of funnel. Thereafter biodiesel is poured into another flask and washed it with potable hot water to remove the residual catalyst and suspended impurities until clean water is obtained. Washed biodiesel is again heated [13] to remove the water which remains in the washing process.

Biodiesel is mixed with diesel oil at different proportions of 6%, 12%, 18%, 24%, 30%, 36% by volume. The physical and chemical properties of biodiesel blends measured according to the standard test methods and compared to diesel oil using ASTM standards. The properties are listed in a Table I.

Table I. Important physicochemical properties of WCO

Test Description	Ref. Std. ASTM 6751	Unit	Limit	B00	B06%	B12%	B18%	B24%	B30%	B36%
Density	D1448	gm/cc	0.800 -0.900	0.832	0.833	0.834	0.835	0.837	0.838	0.841
Calorific Value	D6751	MJ/Kg	34-45	42.50	42.50	42.22	42.09	41.90	41.77	41.55
Cetane Number	D613	-	41-55	49.00	49.45	49.73	49.90	50.13	50.29	50.51
Flash Point	D93	^{0}C	-	64	67.00	76.00	86.00	95.00	102.00	107.00

B. Experimental Set-up

Fig.1 shows the schematic diagram of the experimental set up. The experimental work was carried out on kirloskar make computerised research engine set up (Product 240 PE) at Apex Innovations Pvt. Ltd, Sangli. The engine used is single cylinder, four stroke and direct injection diesel engine coupled with eddy current dynamometer. Technical specification of diesel engine are shown in Table II.

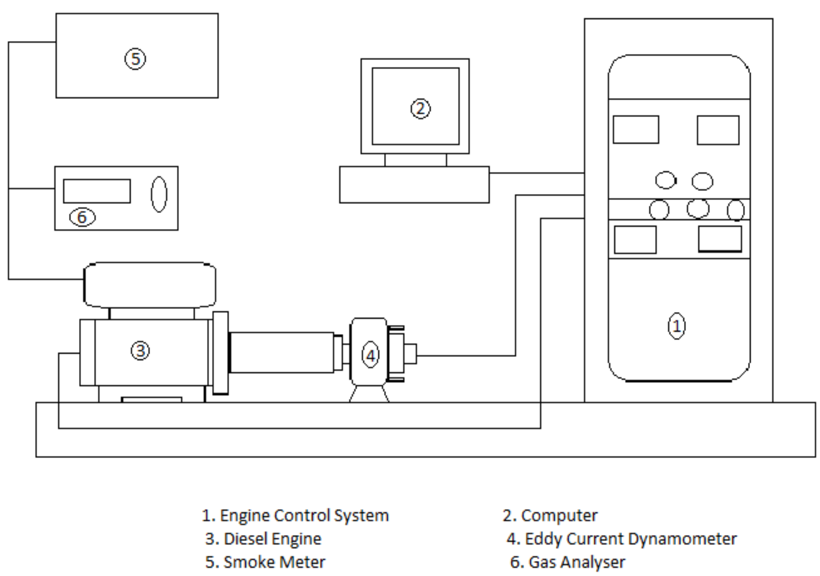

Fig.1. Schematic diagram of the experimental set up.

Maximum power produced by the engine is 3.5 KW at 1500 rpm. Two separate fuel tanks are attached to test rig for diesel fuel and WCO biodiesel. The fuel flow rate was determined by measuring the time required to consume fixed amount of fuel. The thermocouples are used to measure the temperatures at different locations in the experimental set up such as intake air manifold, fuel inlet and exhaust manifold. Emission gas analyser (AVL444N) is used to measure the percentage of CO, HC, NOx in exhaust gas. Smoke emission is measured with the help of smoke meter (AVL437). The Experiment was conducted at 0, 4, 8, 12 kg load at constant rated speed throughout the experiment.

Table II. Specification of Test Engine Set up.

General details	Four stroke, water cooled, variable compression ratio engine, DI
Rated Power	3.5 KW
Number of Cylinder	Single Cylinder
Compression Ratio	12:1 to 18:1
Speed	1500 rpm
Cylinder Diameter	87.5 mm
Stroke length	110 mm
Dynamometer arm length	185 mm

II. Results and Discussions

A. Brake Power

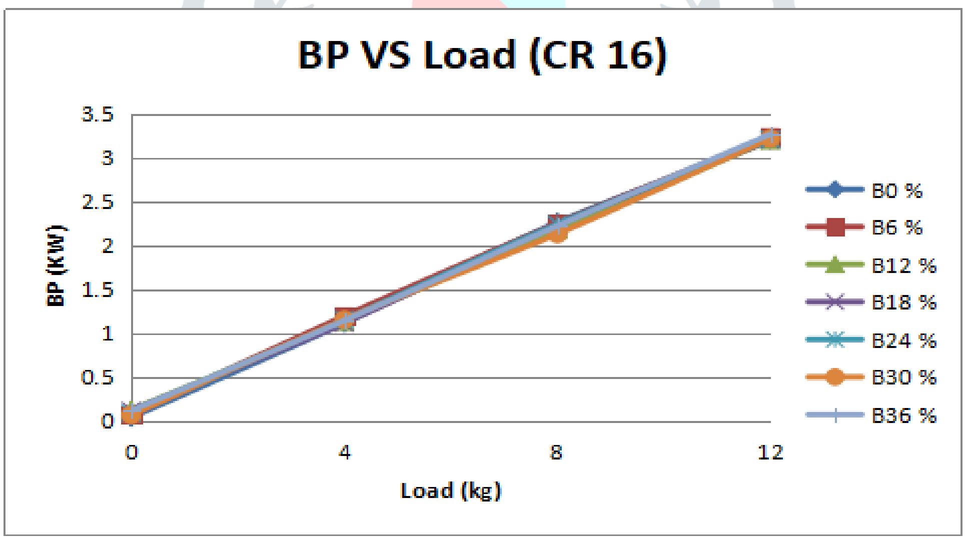

Fig. 2. Variation of brake power with engine load for waste cooking-oil biodiesel blends.

The fig. 2 shows brake power with variable engine load for different blends and diesel. From the graph, brake power increases with increase in engine load and shows similar brake power as that of diesel. Additive EHN is cetane improver and helps in reducing ignition lag by lowering the auto ignition temperature of biodiesel [3], [9], [12]. EHN causes proper mixing of fuel with air and results in complete combustion to produce expected power.

B. Brake Thermal Efficiency

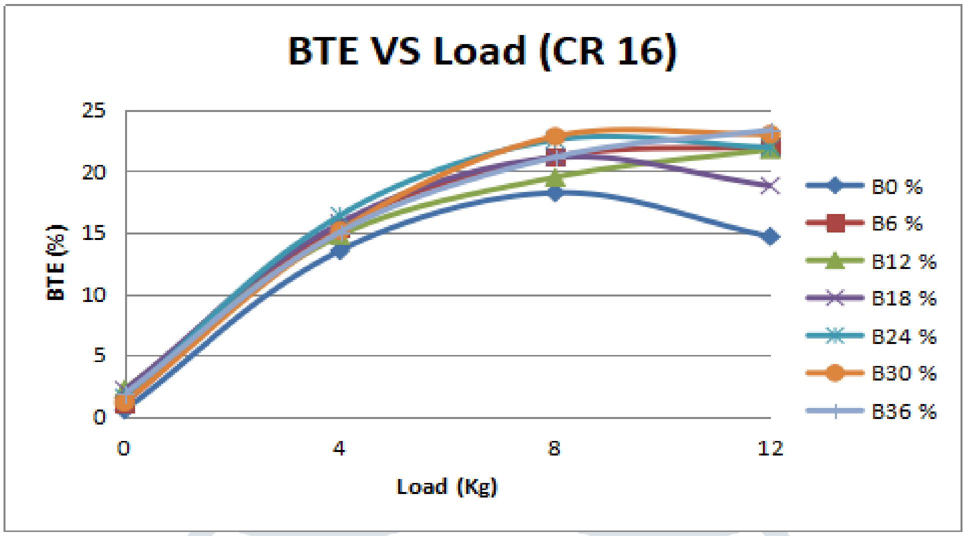

Fig. 3. Variation of brake thermal efficiency with engine load for waste cooking-oil biodiesel blends.

The variation of brake thermal efficiency for different engine load and for different blends is given in fig. 3. It is clearly seen that brake thermal efficiency increases with increase in load up to 8 kg and then partially decrease up to 12 kg load. The possible reason for increase in brake thermal efficiency may be lower viscosity and higher volatility of biodiesel blends compared to diesel due to addition of EHN [16], [21]. The brake thermal efficiency of diesel and B36 blend at 12 kg load is 14.66% and 23.38%.

C. Specific Fuel Consumption

Fig. 4 shows the experimental results of specific fuel consumption for biodiesel blends with engine load as compared to diesel fuel. Specific fuel consumption of an engine is the rate of fuel burnt to produce a unit of thrust. It is seen that specific fuel consumption first decreases with increase in load i.e., up to 4 kg load and then tends to remain constant with increase in load.

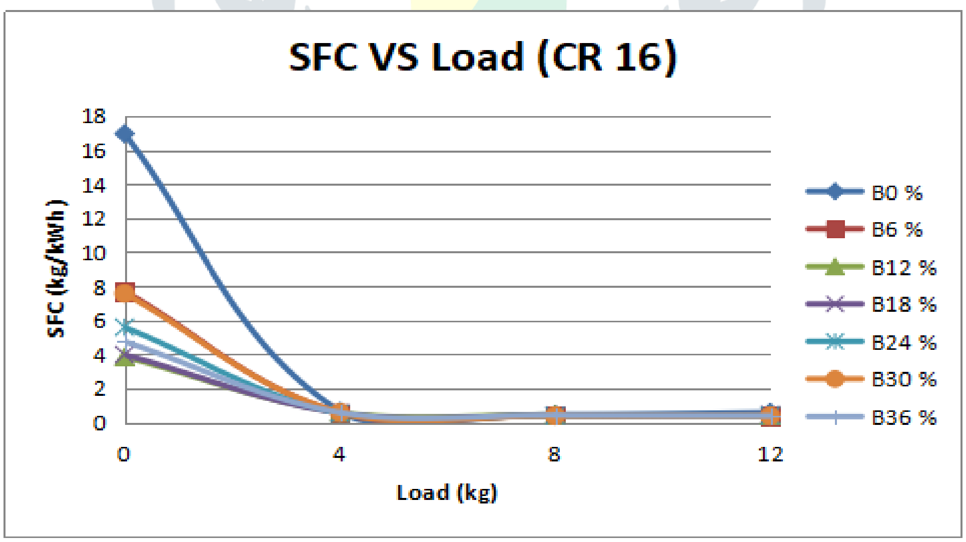

Fig. 4. Variation of specific fuel consumption with engine load for waste cooking-oil biodiesel blends.

At no load condition the specific fuel consumption of biodiesel blends are lower than diesel fuel. This may be due to improved combustion, low self ignition temperature and low viscosity [7], [16], [21]. The specific fuel consumption of the diesel and B36 blend is 16.96 Kg/KW.hr and 0.58 Kg/KW.hr respectively at 0 kg load. Low values of specific fuel consumption are always desirable.

D Carbon Monoxide Emission

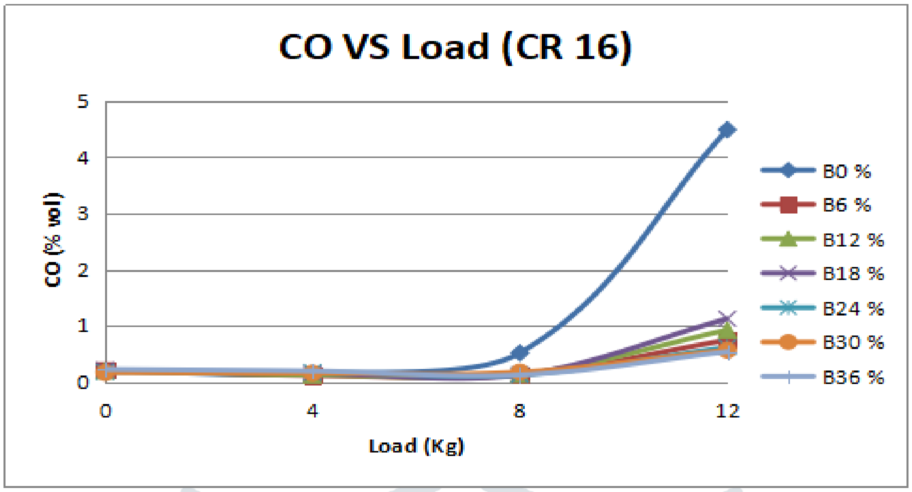

Fig .5. Variation of CO emission with engine load for waste cooking-oil biodiesel blends.

Fig. 5. shows the variation of carbon monoxide emission of the blends and diesel with variable engine load. CO emission remains constant up to 8 kg load and then sharply increases with increase in load. CO emission of biodiesel blends is less compared to diesel fuel. This less value could be attributed to the biodiesel having higher oxygen content than diesel which can result in a complete combustion that leads to reduction in CO emission [18], [23].

E. Hydrocarbon Emission

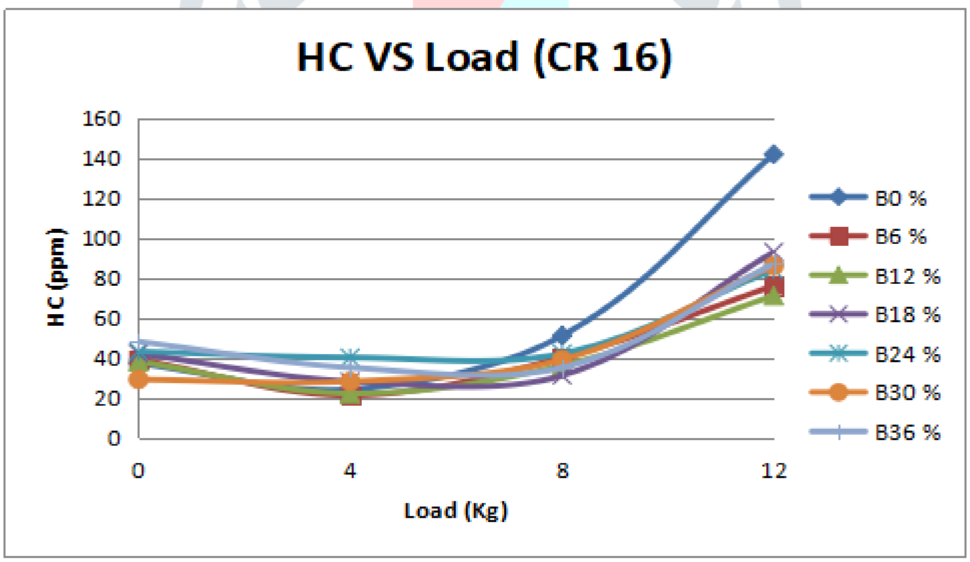

Fig. 6. Variation of HC emission with engine load for waste cooking-oil biodiesel blends.

The fig 6. Shows the variation in unburnt hydrocarbon emission with engine load. It is seen that hydrocarbon emission of biodiesel blends is lower than that of diesel fuel, this may be due to present oxygen in biodiesel breaks down the hydrocarbon into carbon dioxide and water vapour [16]. Addition of EHN which is cetane improver also responsible for reduction in hydrocarbon emission.

F. NOx Emission

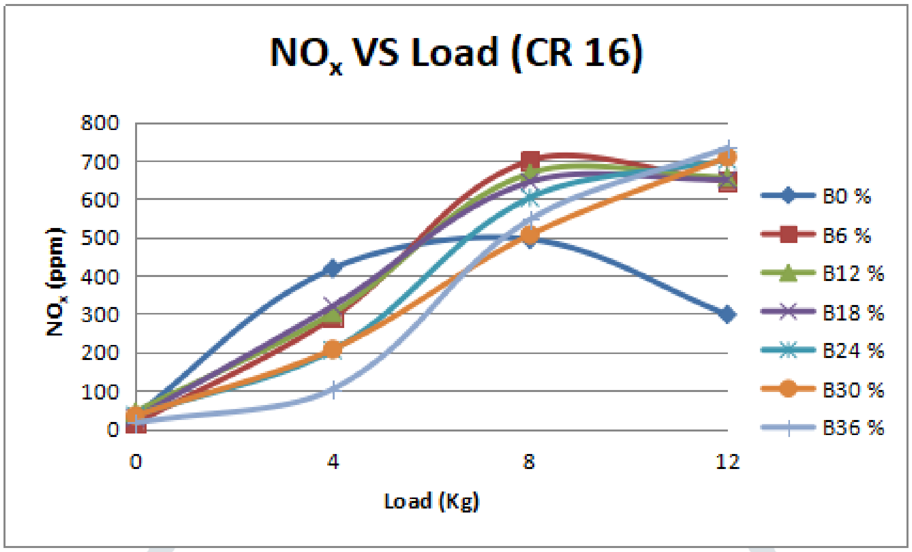

Fig. 7. Variation of NO_x emission with engine load for waste cooking-oil biodiesel blends.

The variation of NOx emission for biodiesel blends with respect to engine load is shown in fig.7. The NOx emission of a diesel fuel increases up to 8 kg load and then start decreasing continuously. But in case of biodiesel blends, the NOx emission increases continuously with the load this may be due to more oxygen content in biodiesel which results in complete combustion [17], [21]. The combustion of biodiesel is sufficiently oxygenated and generates high temperature which favors the production of NOx [22].

G. Smoke Opacity

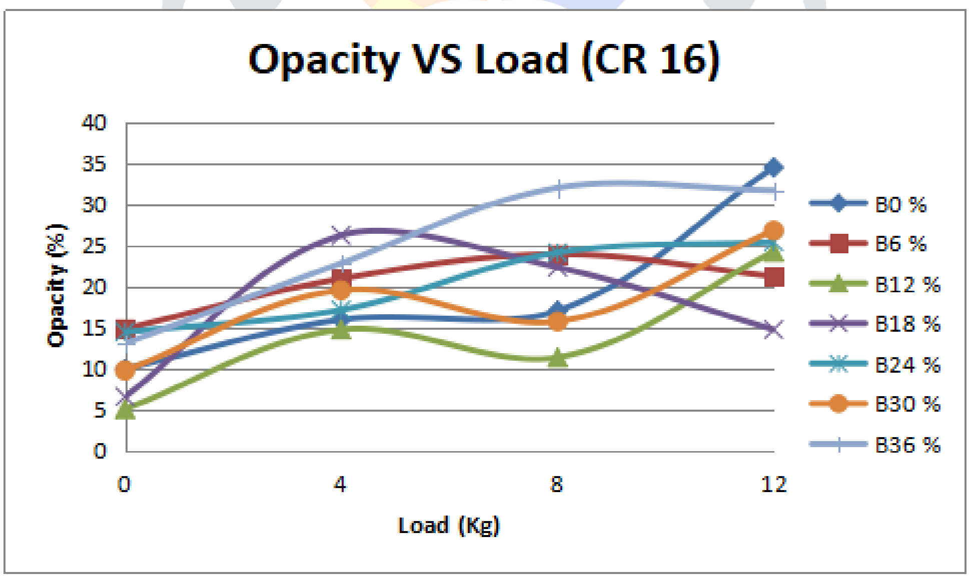

Fig. 8. Variation of smoke emission with engine load for waste cooking-oil biodiesel blends

Variation in smoke emission with respect to engine load is shown in fig. 8. Opacity is the degree to which smoke blocks light and the basis for measuring the amount of smoke coming from a diesel powered engine. From the graph it is seen that smoke opacity is fluctuating in case of all biodiesel blends. As diesel engine running constantly at various load, the temperature of the engine rises to higher level and that's why higher vibration were noticed [16], [17]. This may be the reason for fluctuation of smoke opacity readings at CR 16.

III. Conclusion

The performance and emission characteristics of diesel engine fueled with waste cooking oil biodiesel blends (B06, B12, B18, B24, B30 and B36) were investigated. From the results of BP, BTE, SFC, CO, HC, NOx and Smoke opacity the following conclusions were drawn.

- Brake power increases with increase in load for all the biodiesel blends and shows similar value compared to conventional diesel for all the loads.
- Brake thermal efficiency of biodiesel blends is higher than the diesel fuel due to low viscosity and high volatility. The value of brake thermal efficiency of diesel fuel and B36 blend is 14.66% and 23.38% respectively at higher load.
- Specific fuel consumption of B36 blend is much lower than the diesel fuel. SFC is lower because of better combustion.
- CO and HC emissions are less for biodiesel blends as compared to diesel fuel because of higher oxygen content.
- NOx emissions are increased with the increase in percentage of biodiesel fuel in blend.
- Smoke emission is lower in case of biodiesel fuel as compared to diesel fuel at full load.

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